European Commission

Scientific support for successful implementation of the Natura 2000 network

Focus Area B

Guidance on the application of existing scientific approaches, methods, tools and knowledge for a better implementation of the Birds and Habitat Directives

Environment

Imprint

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Foreword

By DG ENV

With these handbooks, the European Commission intends to support Member State authorities and other stakeholders in making better use of scientific knowledge in implementing the EU Birds and Habitats Directive. Building on the evidence gathered during the Fitness Check of tge EU's nature legislation, this project made the effort to mobilise the scientific community in order to close knowledge gaps, to offer solutions to strategic problems and to enhance the accessibility of scientific information to policy makers and all players involved in implementation.

The handbooks cover the most important areas as identified in the Fitness Check. These comprise methods for monitoring, reporting and assessing conservation status as well as information and approaches required for effective site and network management, including setting conservation objectives, preparing management plans, implementing conservation measures and evaluating their impact.

By analysing relevant knowledge, evidence, tools, approaches and good practices and by bringing together scientists and scientific networks of relevance, the handbooks try to bring the scientific community closer to those that implement the nature directives on the ground.

Background

The Birds Directive established an EU-wide protection regime in 1979 for all bird species naturally occurring in the EU, including a classification by Member States of Special Protection Areas (SPA) for threatened and migratory birds. This approach was extended through the Habitats Directive in 1992. The Habitats Directive also provided for the establishment of a representative system of legally protected areas throughout the EU, known as Special Areas of Conservation (SAC). Together, SPAs and SACs form the Natura 2000 network. The aim of both Directives is to ensure the long-term sustainability of the habitats and species they have been set up to protect. Together the Nature Directives provide a comprehensive protection regime for certain particularly rare and threatened species and for typical and valuable habitats in the EU.

Between 2014 and 2016, the European Commission carried out a Fitness Check of both Directives. Based on this comprehensive evaluation it was concluded that the Nature Directives “remain highly relevant and are fit for purpose”, but also that achieving the objectives and realizing their full potential will depend upon substantially improving their implementation. The review proposed that improvements are needed both in their effectiveness and efficiency and in working in partnership with different stakeholder communities in the Member States and across the EU in order to deliver practical results on the ground.

The Fitness Check also recognised that the existence of remaining knowledge gaps may have led to inefficiencies. Specifically important is access to adequate, reliable knowledge, which is essential for many of the activities associated with the implementation of the directives. The EU Biodiversity Strategy for 2030 formulates 17 commitments (targets) under two main headings: Nature Protection and an EU Nature Restoration Plan. The targets and how to measure success are yet to be defined. Legally binding EU nature restoration targets will be proposed in 2021. By 2030, significant areas of degraded and carbon-rich ecosystems are restored; habitats and species show no deterioration in conservation trends and status; and at least 30% reach favourable conservation status or at least show a positive trend.

The Biodiversity Strategy 2030 highlights nature-based solutions (NBS) as a means to help achieve a number of the restoration ambitions while linking to other policies (primarily climate change mitigation and adaptation and urban biodiversity).

The E-BIND handbooks

The E-BIND handbook(s) are meant to assist decision makers, spatial planners, conservationists, NGOs and other organisations involved in the implementation of the Birds and Habitat Directives. The handbook(s) contains good practical examples, literature references and links to relevant websites.

The two handbooks cover the focus areas:

A. Improving the availability of data and information on species, habitats and sites
B. Scientific support for successful implementation of the Natura 2000 network

Focus Area A, availability of data and information on habitats and species and sites (this handbook) seeks to provide in the lack of data and access to data, including remotely sensed information and monitoring data. The handbook consists of the following three sections:

I. Monitoring of species and habitats
II. Contribution of Remote Sensing Techniques for monitoring Natura 2000 sites
III. Access to data and information

Focus Area B focuses on the effectiveness of the Natura 2000 network and conservation successes, and therefore looks at habitat management and restoration, as well as the wider landscape with Green Infrastructure and Ecosystem services. That handbook consists of the following three sections:

I. Guidance and tools for effective restoration measures for species and habitats
II. Green infrastructure and network coherence
III. Co-benefits (ecosystem services) of measures to consolidate the Natura 2000 network

CHAPTER B.I.

Guidance and tools for effective restoration measures for species and habitats

Kris Decleer & Rienk-Jan Bijlsma

I.1 Introduction

*The Society for Ecological Restoration (SER; Gann et al. 2019) defines **ecological restoration** as the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. It is distinct from **restoration ecology**, the science that supports the practice of ecological restoration, and from other forms of environmental repair in that it seeks to assist recovery of native ecosystems and ecosystem integrity, including semi-natural ecosystems with high nature value due to traditional human use (e.g. heathlands, flower-rich meadows, coppice woodland etc.). Ecological restoration measures have the goal of achieving substantial ecosystem recovery relative to an appropriate reference model, regardless of the time required to achieve recovery. Once recovery has been achieved, any ongoing interventions (e.g. ensuring continued disturbance regimes) would be considered **ecosystem maintenance or management**.*

Ecological restoration is part of a range of activities and interventions which can be implemented to achieve better ecological conditions and to reverse ecosystem degradation. Other activities include remediation and rehabilitation (see chapter 3).

The EU Birds and Habitats directives provide important targets for ecological restoration in Europe. Measures taken pursuant to the Habitats Directive (HD) shall be designed to maintain or restore, at favourable conservation status (FCS), natural habitats and species of wild fauna and flora, taking account of economic, social and cultural requirements as well as regional and local characteristics (HD Article 2 and 3). The concept of FCS includes requirements regarding the natural range, area, structure and functions of natural habitats and, regarding the natural range, area of habitat and population dynamics of species. Natural habitats are defined as terrestrial or aquatic areas distinguished by geographic, abiotic and biotic features, whether entirely natural or semi-natural. In the context of ecological restoration the term natural habitat is synonymous with native ecosystem as used by the SER. Ecological restoration is paramount to achieve target 2 of the EU Biodiversity Strategy to 2020: Maintain and restore ecosystems and their services (*EU, 2011*).

The Biodiversity Strategy 2030 has an important role to play in the next decade, the UN Decade on Ecosystem Restoration. Ecosystem restoration is a spearhead in the new Biodiversity Strategy 2030. It mentions that significant areas of carbon-rich ecosystems are to be restored. Also, legally binding restoration targets are foreseen, a proposal will be developed during 2021. The targets and how to measure success are yet to be defined.

In order to cope with these challenges and dilemmas, successful restoration will largely depend on skilled ecological judgment and knowledge exchange between scientists and practitioners. Carefully considered criteria and use of tools can increase this success.

Main challenges and dilemmas for **effective restoration** result from the following requirements:

- Proper understanding of ecosystem functioning, i.e. abiotic conditions and processes including natural hydrology, natural disturbances and natural gradients in nutrient availability.
- Proper understanding of species (meta)population functioning, i.e. dynamics, reproduction success, genetics, dispersal capacity, food resources, ecological traps, extinction debt.
- Understanding current ecosystem species composition and functioning regarding historical land use and pressures.
- Facilitating (re)colonization of characteristic flora, fauna and vegetation types following abiotic restoration and management.
- Improving ecological resilience regarding pressures and threats at the landscape level (e.g. fragmentation, acidification, nitrogen deposition, climate change).
- Avoiding and controlling the encroachment of invasive alien species.

In this chapter we provide introductory treatments of criteria, concepts and tools, based on principles and standards for the practice of ecological restoration agreed by the SER, in particular:

- **Standards of good practice** for planning and implementing ecological restoration projects (chapter I.2).
- An introduction to the concept of **restorative continuum** to help planners, funders, and implementers understand how nature-based solutions, green infrastructure, and a host of other interventions and activities relate to each other and lead to better conditions on the ground and improve biodiversity (chapter I.3).
- An introduction to the '**LESA-approach**' to facilitate the **selection of appropriate reference ecosystems**, to improve understanding of their ecosystem functioning and to detect desirable restoration measures (chapter I.4).
- An introduction to the **recovery wheel** as a tool helping to design and implement projects, but also for assessment and communication, helping to visually demonstrate how restoration is improving conditions on the ground and to measure effectiveness and outcomes over time (chapter I.5).
- An overview of some existing **science-practice collaboration networks on ecological restoration in Europe** and some helpful information platforms (chapter I.6).

I.2 Standards of good practice for planning and implementing ecological restoration projects

This chapter is largely based on a more comprehensive treatment by *Gann et al. (2019 section 3).*

I.2.1 Planning and design

- Stakeholder engagement should include relevant authorities, owners, managers and local community representatives at the initial planning and throughout the project lifespan.
- Baseline inventories are required to document extent and effects of degradation regarding key ecosystem attributes (and see § 1.5.1): physical conditions, species composition, structural diversity, ecosystem function, external exchanges and absence of threats.
- Identification of reference ecosystem(s) and reference models based on a confrontation of historical and current information: status of current abiotic conditions and pressures and biotic values (habitats, species) as well as their historical context and future threats. See chapter I.4 for details on using a landschape-ecological system analysis (LESA) for this purpose.

- Vision, targets, goals and objectives.* Clear and measurable targets (outcome of the project) goals (desired states of the ecosystems over the medium to long-term) and objectives (desired changes to reach project targets) based on a common understanding of the project vision.
- Analysing and prioritizing logistics and restoration measures, regarding limited resources, risk management, permissions etc.
- Restoration treatment prescription. Clearly stated treatment prescriptions, describing what, where and by whom treatments will be undertaken.

I.2.2 Implementation

- All treatments are undertaken in a manner that is responsive to natural processes and that fosters and protects potential for natural and assisted recovery.
- Adaptive management is applied, informed by the results of monitoring. This practice anticipates unexpected ecosystem responses and corrective changes in activities in accordance with the previous practice.
- Regular communication with stakeholders, preferably based on a communication plan.

I.2.3 Monitoring, documentation, evaluation and reporting

- Monitoring follows from specific targets, measurable goals and objectives identified during planning and design. Preferably methods should be easy-to-use and implemented through participatory processes.
- Documentation of treatment implementation and monitoring activities, including the assessment of treatment effectiveness (evaluation regarding targets, goals and objectives) and enabling adaptive management.
- Reporting and disseminating progress and evaluation results to key stakeholders and a broader public.

I.2.4 Post-implementation maintenance

- The management body is responsible for ongoing maintenance and carrying out post-completion monitoring. Comparison to an appropriate reference model should be ongoing, including surveillance and communication.

* Terms used according to *Gann et al. (2017)* Box 5: Hierarchy of terms used in project planning.

I.3 The restorative continuum concept

The Restorative Continuum (Figure I.1) includes a range of activities and interventions which can be implemented to achieve better ecological conditions and reverse ecosystem degradation and landscape fragmentation by:

- Reducing societal impacts.
- Improving ecological conditions (remediation).
- Repairing ecosystem functions (rehabilitation).
- Recovering native ecosystems (ecological restoration).

The continuum highlights the interconnections among these different activities, and the fact that the specific situation of the locality slated for restorative interventions will dictate which activities are best suited for the different landscape units. As one moves from left to right on the continuum, both ecological health and biodiversity outcomes, and the quality and quantity of ecosystem services, increase. It is also important to note that project-level ecological restoration can and does occur in urban landscapes, agricultural landscapes and elsewhere – it is not restricted to natural ecosystems in protected areas. However, an ecological restoration project or program should aspire to substantial recovery of the native biota and ecosystem functions (*Gann et al. 2019*).

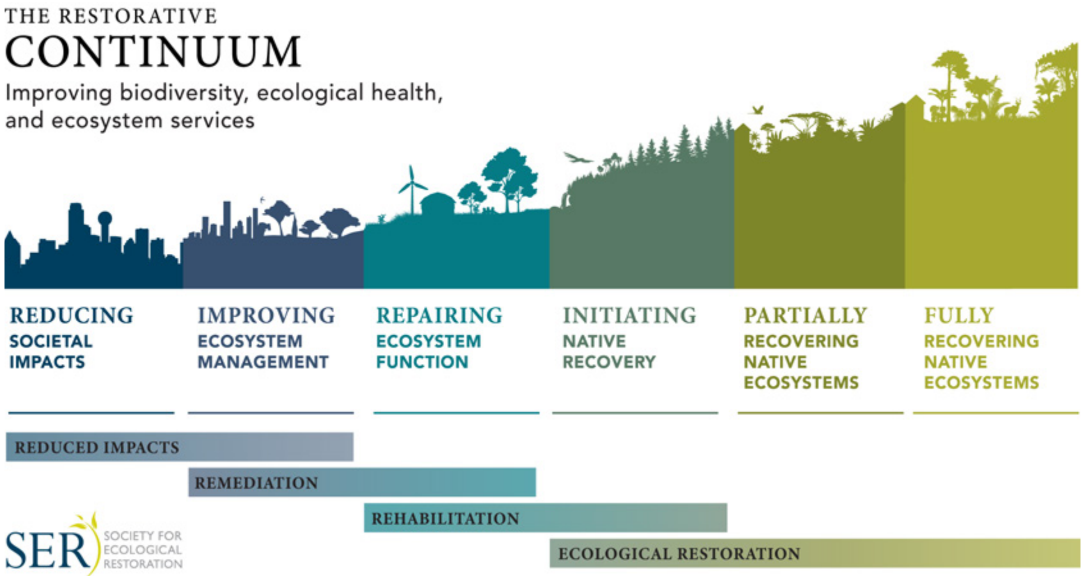


Figure I.1
The restorative continuum presented as overlapping activities to improve environmental conditions and reverse ecosystem degradation and landscape fragmentation (from *Gann et al. 2019*).

I.4 The 'LESA approach' to understand and prioritize reference ecosystem

I.4.1 A plea for a landscape-ecological approach to restoration

Ecological restoration not only gains cumulative value when applied at large scales (*Gann et al. 2019*, Principle 7) but requires analysis and understanding of ecosystem functioning at the landscape level, even when targeted at a local scale. This is because local conditions have been and are shaped by drivers operating at the landscape level and beyond, such as productivity gradients, regional hydrology and land use resulting in changed abiotic and biotic interactions and therefore changed perspectives on long-term viability of habitats and species. Selecting reference ecosystems and models for restoration (see § I.2) must take account of these historical drivers as well as future pressures and threats. Climate change makes local approaches to restore habitats and species even more ineffective if not obsolete.

The underpinning and communication of the selection of reference ecosystems requires a transparent analysis based on commonly available data sources. All the more important when semi-natural habitats or alternative natural habitats are involved. In Europe, the Habitats Directive requires "*to avoid, in the special areas of conservation, the deterioration of natural habitats and the habitats of species as well as disturbance of the species for which the areas have been designated*" (Article 6.2). This adds to possible dilemmas in prioritizing targets for restoration in the case of opportunities for restoring long-term viable natural habitats, in particular if anticipated restoration is at the possible expense of one or more existing natural habitats or species indicative of less optimal or even adverse conditions.

I.4.2 The LESA pathway

The landscape-ecological system analysis (see the side box) was introduced as a tool to allow a transparent and verifiable analysis and evaluation of abiotic conditions, natural habitats and species in Dutch sites as a starting point for management plans including ecological restoration (*Van der Molen et al., 2011*). The landscape-ecological approach acknowledges the importance of regionally operating abiotic and biotic drivers of local diversity and viability of natural habitats and species. The LESA can be included in a procedure to prioritize natural habitats and species as targets for long-term viable development in Natura 2000 sites and to develop a management vision. This extended LESA is in line with SER principles and standards for selecting reference ecosystems (*Gann et al., 2019*).

The LESA approach was used for example in planning the restoration of raised bog remnants in the Netherlands. Historically, the orginal bogs covered large areas of the country including adjacent Germany and Belgium. Although all bog remnants are included in Natura 2000, these sites

The LESA approach

The LESA approach aims at a confrontation of abiotic and biotic patterns and trends at the landscape level and the subsequent evaluation of possible causes for observed changes, resulting in targets for restoration and management.

The analysis includes relationships between patterns in physical-geographic features (geology, geomorphology), soil types and hydrological processes at the landscape level on the one hand, and species composition and spatial distribution of habitats and species on the other hand. Historical distribution data and historical-geographic insights (e.g. on colonization and land use) are key components. Based on knowledge of ecological requirements of habitats and species and of species- and system-specific delays in response to environmental changes, observed biotic changes can be attributed (or hypothesized) to changes in abiotic factors and processes (e.g. groundwater tables, nitrogen deposition) often resulting from modified land use, and to changes in biotic interactions (e.g. invasive species, isolation due to fragmentation).

The extended LESA proceeds by evaluating the (ir) reversibility of changes and trends and the ecological and technical feasibility of restoration approaches, resulting in a vision on long-term viable targets for management and restoration (reference ecosystems or models). This pathway is summarized in Figure I.2.

Data and analyses used in this pathway can be illustrated for the Natura 2000-site Schoorlse Duinen, a c. 1700ha large coastal area in the Netherlands (Figure I.3) with mostly lime-poor dunes (management plan: *Meijer et al. 2016*). First, historical maps show changes in land use for the period 1850–1950 (Figure I.4), including the establishment of large pine plantations. Historical distribution data (1926, 1977) reveal that water tables were much higher during the early 20th century: the moisture-loving shrub Myrica gale virtually disappeared (Figure I.5). During the same period became strongly degraded and surrounded by well-drained agricultural landscapes. Ecohydrological landscape analyses provided insight into the current and historical landscape processes, such as hydrology and land use. This resulted not only in perspectives on improved rainwater retention and maintaining high water levels, but for some sites also on restoring gradients from the nutrient-poor, acid bog centres to the nutrient-richer and more buffered surrounding lagg-zones which are essential habitat for many species of bog ecosystems. Decades of research by the Dutch OBN Knowledge Network for Nature Restoration and Management (see chapter I.6) including several PhD studies resulted in full insight and guidance on the landscape ecology, restoration and management of raised bogs in the Netherlands (summarized in a textbook by *Jansen & Grootjans, 2019*).

We emphasize that, even in Natura 2000 sites, a LESA should not be restricted to designated Natura 2000 features (habitats and species) but should consider all historically and currently characteristic native ecosystems and species in the particular landscape as well as invasive, exotic species. This broader perspective is necessary to anticipate or avoid conflicting demands and to express responsibility for the regionally characteristic biodiversity. After all, the aim of the Habitats Directive is just "*to contribute towards ensuring biodiversity*" (Article 1).

A LESA can benefit strongly from data and analyses already gathered to set favourable reference values (FRVs) for habitats (FRR: favourable reference range; FRA: favourable reference area) and species (FRR; FRP: favourable reference population) at the national level as required for Article 17 reporting. Guidelines for setting these FRVs are available from the Reference portal for reporting under Article 17 of the Habitats Directive and *Bijlsma et al. (2019)*. In using historical information for setting FRVs, the latter report considers the recent past, including about 50 years before the Directive came into force, and the historical past, up to the last two or three centuries, depending on occurrences of major (irreversible) impacts on distribution, population size or area.

species of wet, calcareous dune slacks in the outer dune zone strongly declined as well, such as Parnassia palustris (Figure I.6). The hydrology of the site is determined by an impermeable layer of clay and peat in the subsoil (Figure I.7), absent from the southern area which was part of a former estuary. Due to increased water extraction and evaporation by encroaching scrub and woodland, the water table dropped more than 1m between 1900 and 1980. This change is considered as partly irreversible and restoration measures focus on rewetting large and relatively deep dune slacks only, by cutting c. 140ha of pine forest and facilitating succession to deciduous woodland in another 250ha as well as by removing the vegetation and topsoil in formerly humid dune slacks (Figure I.8 and I.9). Nature values of the corresponding wet habitat types (H2190 Humid dune slacks, H2180 wet Wooded dunes, H3260 Water courses) are considered vulnerable and the restoration and management of these types has priority over measures for inherently dry habitats (such as H2130 Grey dunes, H2140 Decalcified fixed dunes with Empetrum and H2180 dry Wooded dunes) which are considered robust and are allowed to interfere and replace each other within limits.

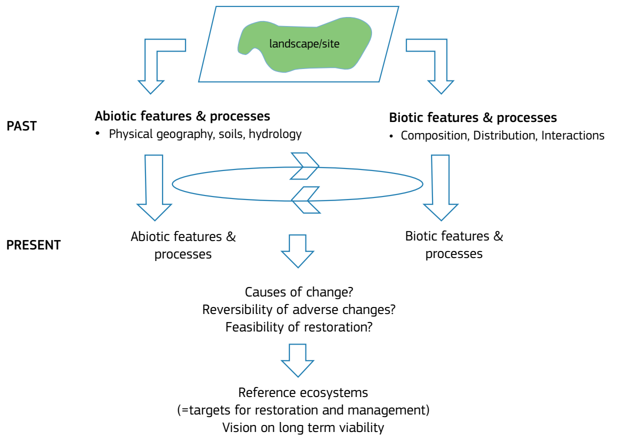


Figure I.2 (left)
Scheme of the LESA pathway showing the confrontation and analysis of historical and current patterns in abiotic and biotic features, followed by an analysis and evaluation of causes of changes and trends. This eventually results in a selection of reference ecosystems serving as targets for restoration and management (adapted from *Bijlsma et al. 2017*).

Figure I.3 (right)
Aerial photo (2018) of Natura 2000 site Schoorlse Duinen (yellow line). Grid: 2,5x2,5km.

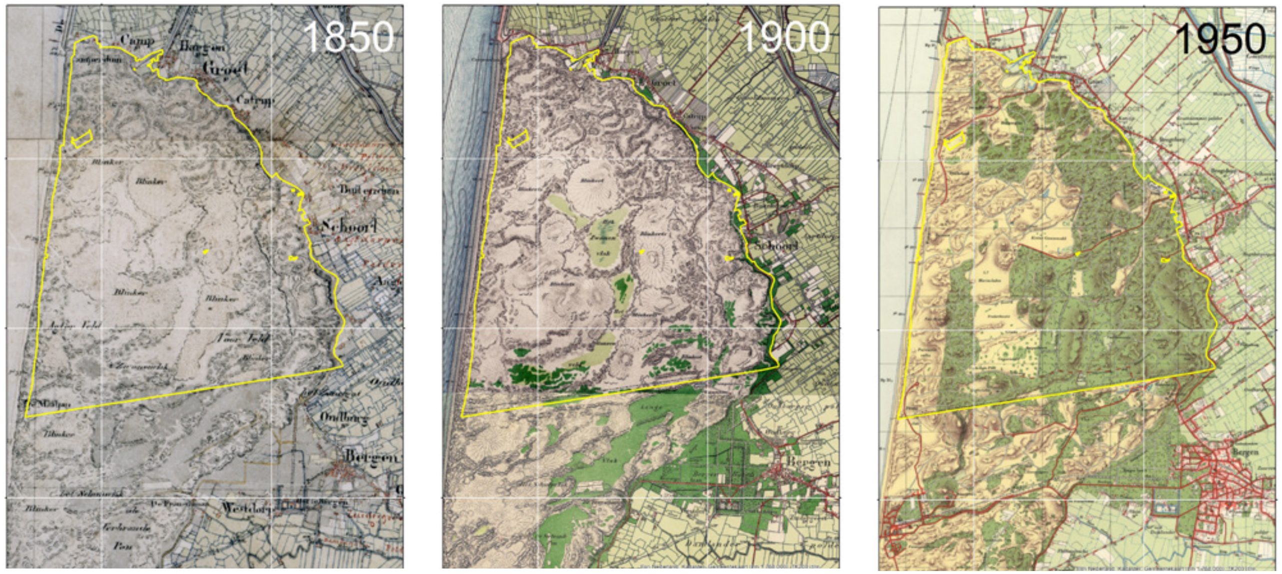
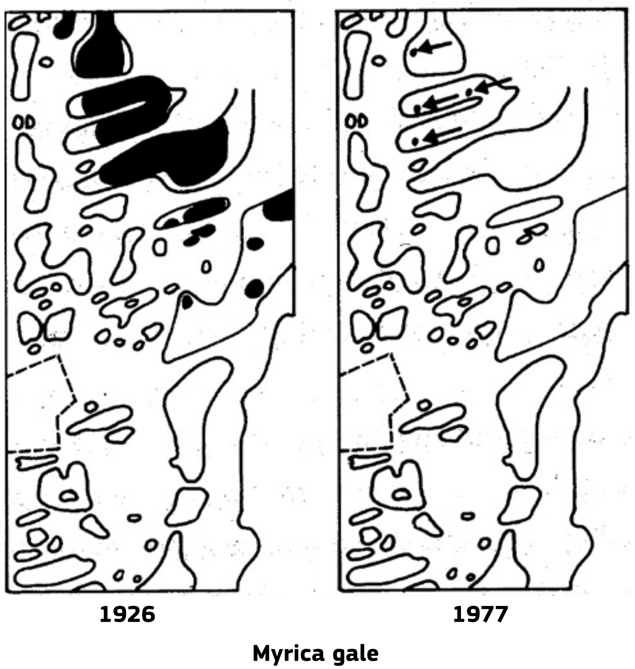


Figure I.4
Historical maps (1850, 1900, 1950) of Natura 2000 site Schoorlse Duinen (same clip as Figure 4.1).



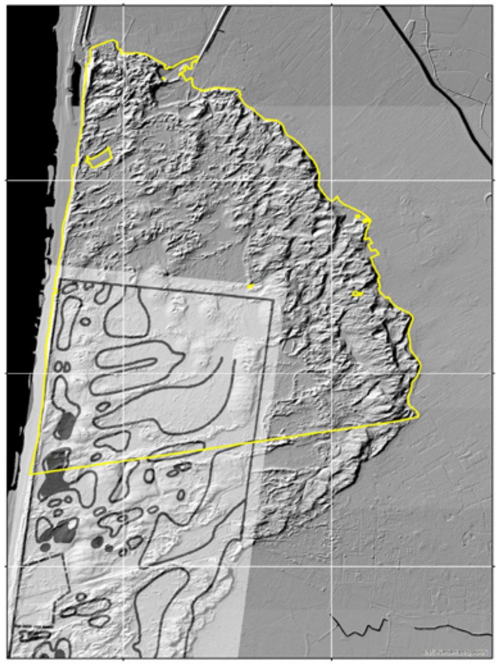


Figure I.5 (left)
Historical distribution (1926, 1977) of the shrub Myrica gale in the Schoorlse Duinen and adjacent dune area (compare Figure I.6) (from *Van Zadelhoff, 1981*)

Figure I.6 (right)
Historical distribution (1926) of the calcicolous Parnassia palustris georeferenced on an elevation map (hill shade) of the Schoorlse Duinen.

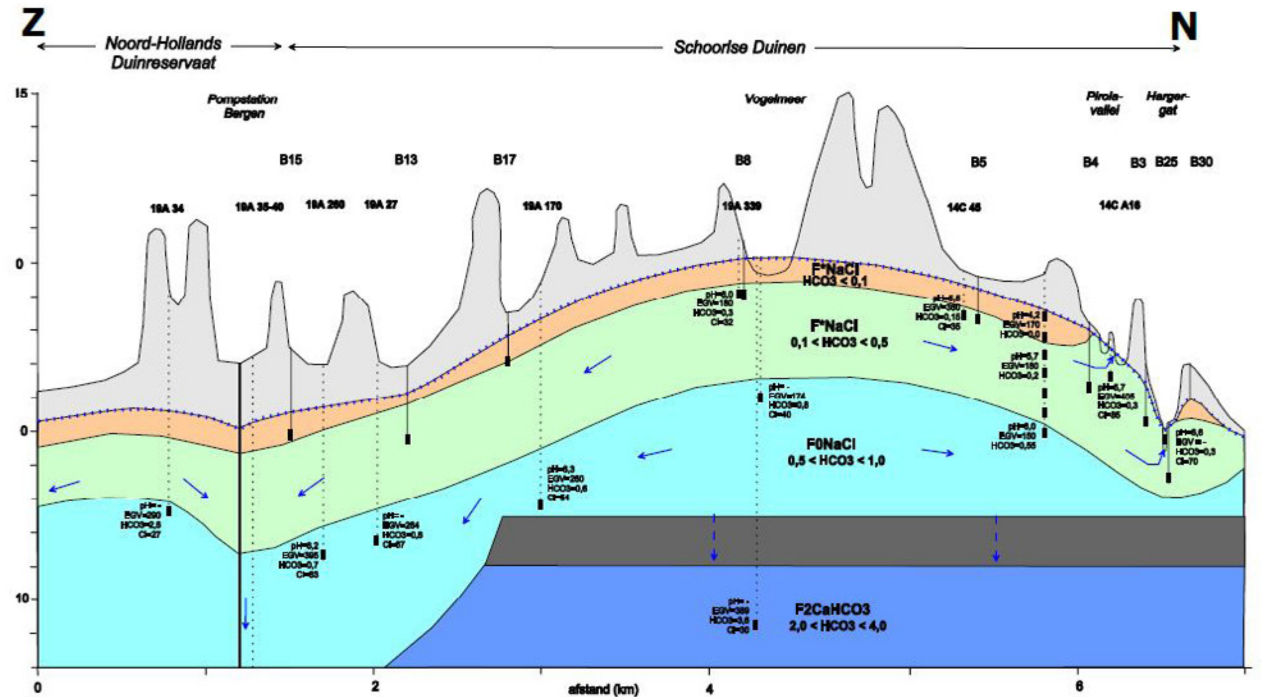


Figure I.7
Geohydrological (north-south) cross-section of the Schoorlse Duinen site and adjacent dune area and the impermeable layer of clay and peat (from *Meijer et al. 2016*).

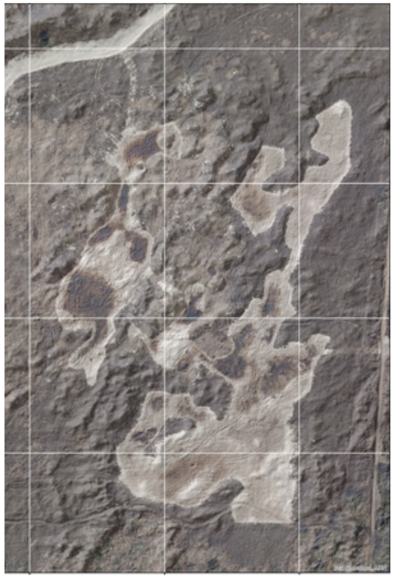


Figure I.8 (left)
Aerial photo (2018) of restoration measures in formerly humid dune slacks within the historical distribution of Myrica gale (compare Figure I.5). Grid: 100x100 m.

Figure I.9 (right)
Field photo of the same restoration measures as in Figure I.9 (photo: R.J. Bijlsma, June 2018).

I.5 Introduction to the 'recovery wheel'

I.5.1 Recovery wheel and five-star rating system for ecological goals*

To help managers, practitioners, and regulatory authorities identify a project's ecological targets and goals and track progress, we present tools for progressively evaluating the degree of native ecosystem recovery over time relative to the reference model – the recovery wheel (Figure I.10) and a five-star rating system (Table I.1). These tools are based on the premise that managers, practitioners, and regulatory authorities either are required or would like to report progress from a baseline condition to a higher level. Indicators are used to describe the state of recovery. (see chapter A.III Data Access).

In the example of fig. I.10, the first wheel represents the baseline condition of each attribute as assessed during the baseline inventory stage of the project. The second wheel depicts a 10-year-old restoration project, where over half its attributes have attained a 4-star condition. Practitioners familiar with the project goals, objectives, site-specific indicators, and recovery levels

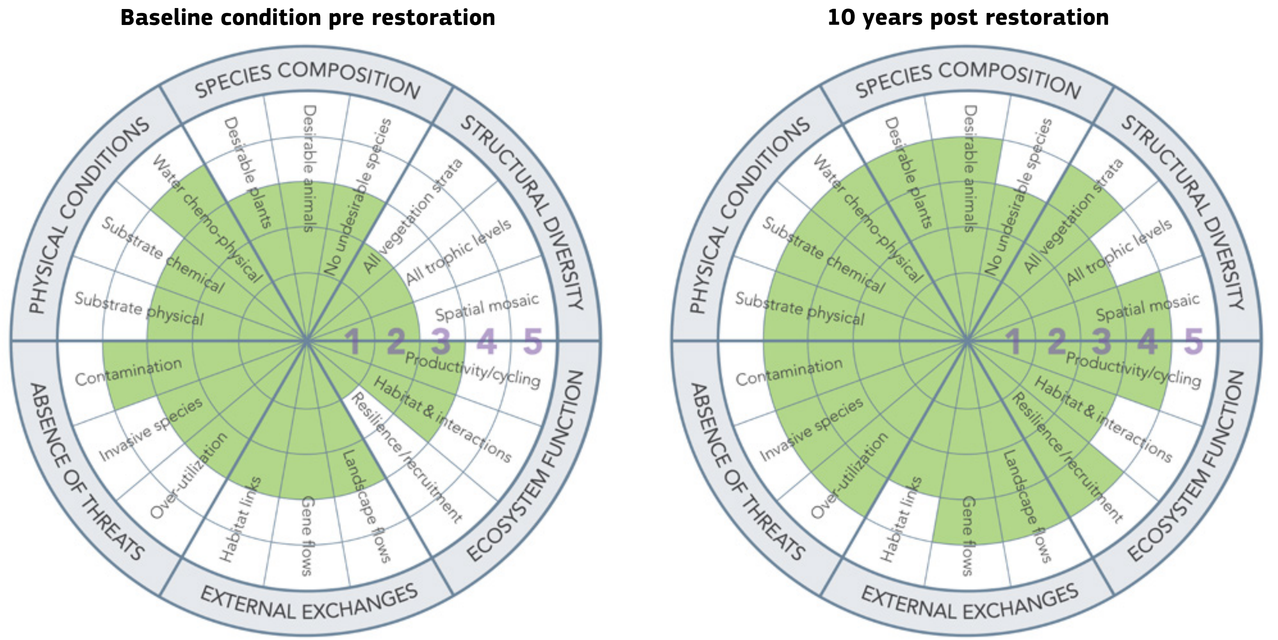


Figure I.10
Recovery wheel – A tool for conveying progress of recovery over time of ecosystem attributes (compared to those of the reference model) (from *Gann et al. 2019*).

* Paragraph 5.1 is largely based on *Gann et al.* (2019 section 2 principle 5)

achieved to date can shade the segments for each sub-attribute after formal or informal evaluation. Note: Sub-attribute labels can be added or modified to best represent a particular project.

Importantly, the 5-star system serves to evaluate the progression of an ecosystem along a trajectory of ecological recovery relative to the reference model. It is not generally intended to evaluate the success of a restoration project against the full range of its goals (for example, social goals can be evaluated using a different tool), the individual performance of practitioners, or to make comparisons between different project sites. Rather, managers are encouraged to use the 5-star rating system to identify their project's ecological targets and goals relative to the six key attributes and to provide a monitoring framework.* The idea is to show progress over time, which can be highly encouraging, even if full recovery is not possible. The 5-star system is most informative when applied at the scale of an individual project or site. It provides a generic framework only, requiring users to develop indicators and a monitoring metric specific to the ecosystem and sub-attributes identified.

Number of stars	**Summary of recovery outcome** (Relative to the appropriate reference model)
★	Ongoing deterioration prevented. Substrates remediated (physically and chemically). Some level of native biota present; future recruitment niches not negated by biotic or abiotic characteristics. Future improvements for all attributes planned and future site management secured.
★★	Threats from adjacent areas starting to be managed or mitigated. Site has a small subset of characteristic native species and low threat from undesirable species onsite. Improved connectivity arranged with adjacent property holders.
★★★	Adjacent threats being managed or mitigated and very low threat from undesirable species onsite. A moderate subset of characteristic native species is established and some evidence of ecosystem function commencing. Improved connectivity in evidence.
★★★★	A substantial subset of characteristic biota present (representing all species groupings), providing evidence of a developing community structure and commencement of ecosystem processes. Improved connectivity established and surrounding threats being managed or mitigated.
★★★★★	Establishment of a characteristic assemblage of biota to a point where structural and trophic complexity to a level of very high similarity to the reference ecosystem is likely to develop with minimal further restoration interventions. Appropriate cross-boundary flows are enabled and commencing, and resilience is restored with return of appropriate disturbance regimes. Long term management arrangements in place.

Table I.1

Summary of generic standards for 1–5 star recovery levels. See Table I.2 for more detailed generic standards for each of the six key ecosystem attributes (from *Gann et al. 2019*).

* Although the five-star rating system is qualitative, and not intended as a substitute for formal quantitative monitoring, it can be adapted for monitoring by developing objective guidelines around the definition of each star. The Recovery Wheel can then be used to develop response ratios (comparison of values of a variable at the restoration site to the reference model) that are commonly employed to measure restoration success.

Attribute	★	★★	★★★	★★★★	★★★★★
Absence of threats	Further deterioration discontinued, and site has tenure and management secured.	Threats from adjacent areas beginning to be managed or mitigated.	All adjacent threats managed or mitigated to a low extent.	All adjacent threats managed or mitigated to an intermediate extent.	All threats managed or mitigated to high extent.
Physical conditions	Gross physical and chemical problems remediated (e.g., nutrient, pH, salinity, contamination or other damage to soil or water.	Substrate chemical and physical properties on track to stabilize within natural range.	Substrate stabilized within natural range and supporting growth of characteristic native biota.	Substrate securely maintaining conditions suitable for ongoing growth and recruitment of characteristic native biota.	Substrate exhibiting physical and chemical characteristics highly similar to that of the reference ecosystem with evidence they can indefinitely sustain species and processes.
Species composition	Colonizing native species (e.g., ~2% of species in the reference ecosystem). Moderate onsite threat from nonnative invasive or undesirable species. No threat to regeneration niches or future successions.	A small subset of characteristic native species establishing (e.g., ~10% of reference). Low onsite threat from nonnative invasive or undesirable species.	A subset of key native species (e.g., ~25% of reference) establishing over substantial proportions of the site. Very low onsite threat from undesirable species.	Substantial diversity of characteristic native biota (e.g. ~60% of reference) present on the site and representing a wide diversity of species groups. No onsite threat from undesirable species.	High diversity of characteristic native species (e.g., >80% of reference) across the site, with high similarity to the reference ecosystem; improved potential for colonization of more species over time.
Structural diversity	One or fewer biological strata present and no spatial patterning or community trophic complexity relative to reference ecosystem.	More strata present but low spatial patterning and trophic complexity, relative to reference ecosystem	Most strata present and some spatial patterning and trophic complexity relative to reference site.	All strata present. Spatial patterning evident and substantial trophic complexity developing, relative to the reference ecosystem.	All strata present and spatial patterning and trophic complexity high. Further complexity and spatial patterning able to self-organize to highly resemble reference ecosystem.
Ecosystem function	Substrates and hydrology are at a foundational stage only, capable of future development of functions similar to the reference.	Substrates and hydrology show increased potential for a wider range of functions including nutrient cycling, and provision of habitats/ resources for other species.	Evidence of functions commencing – e.g., nutrient cycling, water filtration and provision of habitat resources for a range of species.	Substantial evidence of key functions and processes commencing including reproduction, dispersal and recruitment of species.	Considerable evidence of functions and processes on a secure trajectory towards reference and evidence of ecosystem resilience likely after reinstatement of appropriate disturbance regimes.
	Potential for exchanges (e.g. of species, genes, water, fire) with surrounding landscape or aquatic environment identified.	Connectivity for enhanced positive (and minimized negative) exchanges arranged through cooperation with stakeholders. Linkages being reinstated.	Positive exchanges between site and external environment starting to be evident (e.g., more species, flows etc.).	High level of positive exchanges with other natural areas established; control of pest species and undesirable disturbances.	Evidence that external exchanges are highly similar to reference, and long-term integrated management arrangements with broader landscape in place and operative.

Table I.2

Sample 1–5 star recovery scale interpreted in the context of the six key ecosystem attributes used to measure progress along a trajectory of recovery. This 5-star scale represents a gradient from very low to very high similarity to the reference model. It provides a generic framework only, requiring users to develop indicators and a monitoring metric specific to the ecosystem and sub-attributes identified (from *Gann et al. 2019*).

I.5.2 Connecting the recovery wheel to EU habitats directive reporting

The recovery scale interpreted in the context of the six key ecosystem attributes can contribute greatly in drawing up management plans of Natura 2000 sites regarding degraded habitat types and habitats for species. Moreover, this approach can easily be connected with several aspects of EU Habitats Directive reporting.

At the site level, Standard Data Forms (SDF) require for habitat types assessments of Representativity (A excellent, B good, C significant), degree of conservation of structure (I excellent, II structure well conserved, III average or partially degraded structure), degree of conservation of functions (I excellent prospects, II good prospects, III average or unfavourable prospects) and of restoration possibilities (I easy, II restoration possible with an average effort, III restoration difficult or impossible) which directly relate respectively to the key ecosystem attributes species composition, physical conditions & structural diversity and ecosystem functions whereas restoration possibilities relate to decisions from the planning and design of restoration at site level. For species the SDF likewise requires assessments for the Degree of conservation of the features of the habitat important for the species and restoration possibilities.

At the national (biogeographic) level Article 17-reporting can benefit from concepts underlying the 5-star recovery scale and recovery wheel, in particular regarding the conservation status parameters habitats for the species (Annex B Species) and structure and functions (Annex D Habitat types) as well as future prospects (both Habitat types and Species). The reporting formats emphasize assessments based on short-term and long-term trends which require proper monitoring (see § I.2.3 and Chapter A.1, on monitoring).

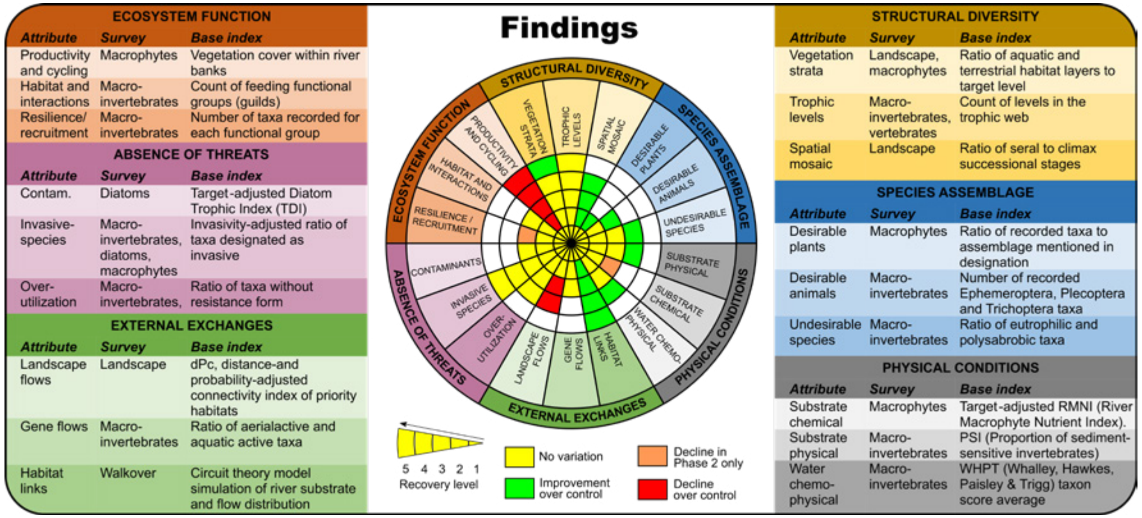


Figure I.11

Use of the recovery wheel in practice

In the UK the Recovery Wheel concept was tested to detect recovery trends in a river restoration project (*Fioratti, 2017*). A set of 6 key attributes and 18 sub-attributes were selected to assess recovery trends relative to an unrestored control site. For each attribute appropriate metrics were defined. The metrics are based on a combination of biotic and landscape indicators integrated in a comprehensive sampling protocol, designed to be cost-effective and reliable.

For each indicator the results were scored on a 1 to 5 scale of increasing recovery. In this case the results were presented in one wheel only, with the use of different colours to indicate positive, negative or no change relative to the control. Also, change over time was assessed with a phase 1 (results after 2 years) and a phase 2 (results after 1 year). Achievement of complete recovery is evaluated with a comparison of the metric to a set threshold or range delimited by a lower and an upper value. Lower recovery stages are assigned as a function of the distance of the reading from the threshold or range.

For example, the indicator 'desirable animals' improved with one level 2 years after the restoration. The indicator 'chemical quality of the substrate', based on a River Macrophyte Nutrient Index, declined in the first year with one level, but improved again with one level after the 2nd year. The results for the indicator 'invasive species' showed no difference after restoration. For the attribute 'productivity' the indicator 'vegetation cover' was used and the results showed a decline with 5 levels after restoration.

It is envisaged that the identification of suitable quantitative indices and an affordable and flexible sampling protocol for the recovery wheel will expand substantially the scope and potential of this innovative tool for science-informed and target-based ecosystem restoration.

I.6 Science-practice collaboration networks in Europe and information platforms

Successful interaction and knowledge transfer between researchers, policymakers and practitioners is essential to foster cost-effective restoration of ecosystems. While many nature conservation agencies and NGOs employ staff with a proper scientific education and background, it is often not evident for them to keep track of the latest insights related to specific and often complex matters in restoration ecology and ecosystem functioning. For a given situation, specific knowledge may be lacking that is essential to assess bottlenecks for successful restoration and to plan appropriate measures. Nor is it evident for them to set up time-consuming field experiments to test hypotheses according to robust scientific methods and techniques. Restoring conditions for the recovery of endangered species is another illustration of why expert involvement may be necessary at project level. Researchers can also help in the training of practitioners (or 'training of the trainers'), in setting up or executing baseline or follow-up monitoring of restoration projects, in reporting and in validation of data and results in scientific publications in order to internationally share information and promote cross-border collaboration. Scientists can also help in the underpinning of restoration priorities at different geographic scales.

English is the universal language for communication between researchers, but in multilingual Europe, language is often a barrier for successful knowledge exchange and collaboration at the local level. Having science-practice collaboration platforms and networks in the local language is a huge benefit, especially for practitioners and volunteers. Involvement of local scientists also builds more sustainable networks as they are more familiar with the local actors and the local ecosystem conditions and functioning, which may vary between different European regions. A good understanding of the local legal and cultural context is important as well.

In the rapidly evolving field of restoration ecology and conservation biology, science-practice collaboration is of uttermost importance. Unfortunately, actively bridging the 'gap' between science and practice is still undervalued, as made evident by the limited efforts of the science and nature administration bodies at national and European level. A more active government support across the policy domains of 'science' and 'practice' could guarantee the long-term sustainability of capacity building, especially if some funding is available for facilitating applied research and training by scientists and for active dissemination of best-practice information through digital platforms, field courses, workshops, conferences and publications. The Dutch OBN Knowledge Network (see box) is an excellent example that deserves emulation in other European countries.

In several European countries national science-practice collaboration networks developed spontaneously and gradually over the last one or two decades. Some merely operate at European or even global level, are dedicated to ecological restoration in general, also include ecosystem

The Dutch Knowledge Network for Restoration and Management of Nature (OBN)

Based on: Giulia Variara, 2019 (compilation & editing). www.natuurkennis.nl/Uploaded_files/Publicaties/obn-english-2019-2.14f730.pdf

Organisation and financing

The OBN Knowledge Network includes

- researchers from institutes and universities,
- site managers and private land owners,
- representatives from consultancies and NGOs
- representatives from governmental bodies such as provinces and water boards.

The objective is to closely cooperate in the restoration of ecosystems and nature reserves in all major Dutch landscapes.

Since 2006 the network formulates a mission statement and knowledge agenda each 4 to 5 years which is leading in all activities. Nine landscape-based '**Expert Teams**' are working on the development, dissemination and implementation of knowledge on restoration and rehabilitation of ecosystems, on issues regarding Natura 2000 and the EU Water Framework Directive, as well as on the conservation of individual species. Atmospheric nitrogen deposition, climate change, sea level rise, coastal defence, flood risks and agricultural practise are main environmental concerns.

Site managers, together with policy makers and researchers identify knowledge gaps to enable cost-efficient and effective nature restoration and management measures. A permanent secretary overlooks the activities of the expert teams and research projects, supported by an advisory board. OBN research projects ('**case studies**') are being allocated via calls for tenders to research institutes. Results are communicated in reports, brochures, newsletters, a website, publications in scientific journals and more…

…popular nature magazines, interactive workshops management issues or purely focus on particular ecosystem types or species groups. Some networks and platforms share information for free, other expert groups can be involved with some financial compensation.

In the following overview a (non-limitative) list of the most relevant existing networks and platforms in Europe is presented with brief information and web links. In view of the existing policy targets, the sense of urgency to tackle the biodiversity and climate crisis and the many challenges in ecosystem restoration, more national and/or European funding of these groups would enable a boost in the highly-needed, sustainable and multidisciplinary science-practice collaboration with, in the end, more cost-effective ecosystem restoration and recovery of endangered species populations at both national and European scale.

I.6.1 Umbrella networks active in the field of ecological restoration

SER Europe (European Chapter of the Society for Ecological Restoration)
chapter.ser.org/europe; contact: info@ser-europe.org

The SER is a global network of restoration experts and enthusiasts, connecting and educating the restoration community by:

- biennial European conferences where researchers, practitioners, policy makers and students come together to exchange ideas, showcase their work, forge new alliances and participate in discussions and field trips. Example: sere2021.org
- biennial world conferences on ecological restoration
- promoting and co-organising regional workshops and conferences
- promoting and co-organising 'summer schools' and other training and educational events
- SER's peer-reviewed journal 'Restoration Ecology', which highlights advances in restoration science
- a global Restoration Resource Center: www.ser-rrc.org
- a European Knowledge Base on Ecological Restoration: chapter.ser.org/europe/knowledge-base/overview
- Reports and publications: www.ser.org/page/SERDocuments; chapter.ser.org/europe/publications/special-issues-conference-books
- promoting other reference publications: chapter.ser.org/europe/publications/recommended-books-and-reports

and field trainings. Within the OBN Knowledge Network field workshops are an important way of knowledge exchange. During these workshops research outputs and experiences with management techniques are being shared and discussed.

The network is financed by the Dutch National and Provincial governments. In 2018 the network received an operational grant of 1,948,000 euro in total. 1,188,000 euro was spend to pay for research projects (normally 6–8 yrs per project); 253,800 euro for the functioning of the expert groups; 215,680 euro for knowledge distribution (communication, publications, newsletter, symposia, website) and 290,520 euro for the coordination (secretariat staff etc.). Some income is acquired by subscriptions to attend workshops and field trainings.

The Expert Teams
The set-up of eight Expert Teams has been based on the various landscapes that occur in the Netherlands: Brook Valleys, Dry Sandy Areas, Wet Sandy Areas, Dunes and Coastal Areas, Colline Areas, Fen and Sea Clay Areas, Riverine Areas and Agricultural and Rural Areas. An additional expert group on fauna is established to provide advice to the Expert Teams on fauna aspects.

The Expert Teams form the core vehicle of the OBN Knowledge Network. These teams formulate research questions aimed at solving (long-term) management problems. They also supervise research projects and disseminate knowledge by means of reports, scientific papers, brochures, expert reviews, lectures, field symposiums, and a Nature Portal (via internet).

In all landscapes, changes in land use, desiccation, eutrophication, atmospheric nitrogen deposition, acidification, often biased by uncoordinated nature policies and nature management, still have a huge impact on habitats and species, causing a drastic deterioration …
… of the once very rich cultural-historical and land-

» active collaboration and networking with regional restoration networks and partners who subscribe to the quality standards and values of SER Europe, such as:

→ **REVER: the French restoration experts network**. REVER or "*Le Réseau d'Échanges et de Valorisation en Écologie de la Restauration*" has pretty much the same goals as SER Europe, but is restricted to France. They organize national conferences and other activities that link the French restoration community. In 2014 REVER became affiliated member of SER Europe. More information about REVER: www.reseau-rever.org (website in French). Contact person: Prof. Dr. Elise Buisson, elise.buisson@univ-avignon.fr.

→ **FBER: the Finnish Board on Ecological Restoration** is a national collaborative group consisting of managers, scientists, and experts working with habitat restoration and the management of cultural habitats. The group supports restoration and nature management actions both on state-owned and private land. Four expert groups work under the Steering Group: Peatland Restoration Expert Group, Forest Restoration Expert Group, Freshwater Habitats Restoration Expert Group and Semi-Natural Grassland Expert Group. The Restoration Board together with the expert groups e.g. prepares restoration handbooks and organizes seminars. The Restoration Board is coordinated by Metsähallitus and Finnish Environment Institute. Link to the Finnish web pages: www.metsa.fi/en/nature-and-heritage/habitats. Contact person: Jussi Päivinen, jussi.paivinen@metsa.fi.

→ **SIRF: the Italian Society of Forest Restoration** is based in the Department of Agriculture, Forestry, Nature and Energy (DAFNE) of Tuscia University (Italy). SIRF was established in 2012 and aims at: (1) showing the illegal or incorrect actions in forest systems, chief causes of forests and environmental degradation; (2) promoting the application of the principles of forestry and environmental restoration; (3) promoting biodiversity conservation and sustainable management of forest resources; (4) supporting the improvement of the quality of the forest and agricultural landscape. SIRF participates in research projects, provides consultancy, training and education and (co-)organizes meetings and conferences. SIRF became an affiliated member of SER Europe in 2015. Contact person: Prof. Dr. Bartolomeo Schirone, schirone@unitus.it.

→ **AEET: Asociación Española de Ecología Terrestre**. The Spanish Association for Terrestrial Ecology (AEET) is the largest ecological society in Spain and a member of the European Ecological Federation. Its working group on Ecological Restoration has promoted knowledge exchange on issues related to this topic over the last decade. Contact person: Josu D. Alday, osucham@gmail.com, www.aeet.org/Restauracion_Ecologica_133_p.htm.

scape values and the originally high biodiversity. Especially in the dune and coastal areas and along the main river systems, safety aspects and drinking water production often set special preconditions to nature management.

Case studies

In this section some results are presented which give an overview of topics concerning restoration and rehabilitation of important ecosystems in the Dutch landscapes.

CASE STUDY 'Nitrogen deposition': Forest biodiversity on mineral-poor soils in dry sandy areas
This OBN project focused on the possible relationships between biodiversity loss and nitrogen deposition together with the inevitably associated acidification. It is known that nitrogen deposition affects the amino acid composition of plants. Acidified forests in particular are sensitive to amino-acid problems due to nitrogen deposition.

The results of this study show that the nitrogen deposition and the acidification cause shortages of plant mineral nutrients, compromising amino acid production in plants, which in turn affects the fauna communities leading to an advanced degradation of forest ecosystem quality. Two scientifically realistic ...
... restoration pathways are shown: the first is to have

- **OBN: Dutch Knowledge Network for Restoration and Management of Nature**. The Dutch OBN Knowledge Network for Nature Restoration and Management is an independent and innovative platform where policymakers, site managers and scientists cooperate in the management and restoration of natural areas. Science and nature management jointly look for the most effective approaches to enhance sustainable conservation of important ecosystems in the Dutch landscapes (see box). More information: www.natuurkennis.nl/english/obn-knowledge-network/knowledge-network/knowledge-network-for-restoration-and-management-of-nature-in-the-netherlands. Brochure with more information about OBN: dt.natuurkennis.nl/uploads/OBN_English_Brochure_2016.pdf (English). Website in Dutch: www.natuurkennis.nl. Contact person: Wim Wiersinga (w.wiersinga@vbne.nl) or Mark Brunsveld (m.brunsveld@vbne.nl).

- **Netzwerk Renaturierung – German Restoration Network (GRN)**. The German Restoration Network (GRN) was founded in 2016 at the Freising Conference of the Society for Ecological Restoration Europe. The GRN has members coming from universities as well as from restoration practice in Germany, Austria and Switzerland. A special feature of the network is the high and still increasing proportion of practitioners working in nature conservation authorities, NGOs, planning agencies or wild plant propagation companies. Learning from practical experiences and solving future challenges in ecological restoration is a focus of GRN. Website: renaweb.standortsanalyse.net. Contact person: Sabine.Tischew@hs-anhalt.de.

- **CIEEM: the UK Chartered Institute of Ecology and Environmental Management**. CIEEM is the leading professional membership body representing and supporting ecologists and environmental managers in the UK, Ireland and abroad. CIEEM was formed in 1991 as the Institute of Ecology and Environmental Management. From small beginnings, it has grown into an increasingly influential professional body – setting standards, sharing knowledge and providing sound advice to governments on all aspects of ecological and natural environmental management practice. Website: cieem.net. Contact person for the Restoration and Habitat Creation Interest Group of CIEEM: j.mitchley@reading.ac.uk.

- **Rede Portuguesa de Restauro Ecológico**: The Portugese Network for Ecological Restoration was created in 2019 and signed a memorandum of understanding with SER Europe on 02/08/2019 at the Faculty of Science of the University of Lisbon, at the occasion of the Congress of the European Ecology Federation. Contact person: Alice Nunes, amanunes@fc.ul.pt or rede.portuguesa.restauro@gmail.com.

a further reduction of nitrogen deposition and the second is to lift the mineral deficiency of trees by replenishing the system with minerals.

CASE STUDY Dune and Coastal Area: Grazing management related to fauna communities restoration in dry dune grasslands
This project investigated if and how grazing management can affect the fauna communities of open coastal dune habitats (H2130, H2140, H2150) in order to restore the biodiversity of this important landscape.

The study of differences between grazed and ungrazed plots along the whole Dutch coastline shows that grazing in general has a positive effect on fauna communities of dry open dune habitat. A low grazing pressure is preferable in calcium-rich dunes since it facilitates rabbits, characteristic butterfly species and other flower-visiting insects and has little effect on soil fauna. In calcium-poor dunes grazing decreases N-availability, which is necessary to temper plant growth. The high grazing pressure seems beneficial for the number of characteristic breeding birds, but detrimental to soil fauna, butterflies and other flower-visiting insects.

CASE STUDY Wetlands: Water level fluctuations in peatlands: relation between hydrology, ecosystem, dynamics and Natura 2000 habitat types
This research considered the ecological benefits and drawbacks of the re-establishment of fluctuating water levels as a management tool in different Natura 2000 habitat types to support water and nature management authorities in decision-making. The potential drawbacks of temporary lowered surface water levels, and related lowered water tables in the peat soil, seem to be more important than the potential benefits, overall at the expense of the development of protected brown moss vegetation in rich fens. Desiccation of the topsoil in rich fens should be avoided. In ...
... contrast to drought, periods of inundation with

Eurosite
Eurosite is the network for Europe's natural site managers, bringing together non-governmental and governmental organisations, as well as individuals and organisations. Founded in 1989, the network has grown to include members across Europe. The mission of Eurosite is to provide opportunities for practitioners to network and exchange experience on practical nature management. Eurosite organizes and participates in many educational events, such as conferences, workshops, trainings and research projects. Website: www.eurosite.org.

I.6.2 Thematic Expert Networks

SPECIES

» Planta Europe Network: www.plantaeuropa.com
» BatLife Europe: www.batlife-europe.info
» European Mammal Foundation: www.european-mammals.org
» BirdLife International: www.birdlife.org/europe-and-central-asia
» International Wader Study Group: www.waderstudygroup.org/publications
» Reptile Amphibian Conservation Europe: www.arc-trust.org/news/the-race-is-on
» Societas Europaea Herpetologica: www.seh-herpetology.org
» Buglife-The Invertebrate Conservation Trust: www.buglife.org.uk; www.buglife.org.uk/resources/habitat-management
» Butterfly Conservation Europe: www.bc-europe.eu
» European Red List Species: www.iucnredlist.org/search?query=Europe&searchType=species
» European Committee for Conservation of Bryophytes: eccbbryo.nhmus.hu
» European Network on Invasive Alien Species: www.nobanis.org

ECOSYSTEMS

» International Mire Conservation Group: www.imcg.net/pages/home.php
» Wetlands International: europe.wetlands.org
» European Centre for River Restoration: www.ecrr.org
» Alliance for freshwater life: allianceforfreshwaterlife.org
» European Pond Conservation Network: www.europeanponds.org

base-rich water in summer can be favorable. The Ca- and Fe-contents of peat soils of and surface water turned out to strongly determine the responses to water table fluctuations in the peat soil.

CASE STUDY Dry Sandy Areas: Heathland recovery by incorporating extensive farmland
In the Netherlands, heathland natural areas harbour several Natura 2000 protected habitat types (H2310; H2330; H3160; H4010; H4030; H5130; H6230). Characteristic fauna species of these ecosystems are still in decline. One cause is the loss of land use gradients in the remaining heathland landscape. In the past, extensive agricultural fields linked the heathlands including fields near the villages; nowadays, this situation is rare. The project investigated the contribution of reinstated relatively nutrient-rich and dynamic habitats to the biodiversity of heathland landscapes.

The results show that in order to restore the faunal biodiversity, heathland management should incorporate extensive farmland management schemes.

CASE STUDY Colline Areas: Restoration and expansion of unimproved downland in Southern Limburg
The unimproved downland in Southern Limburg (with loess and calcareous soils) provides habitat for many species of Natura 2000 types H6210 (calcareous grasslands) and H6230 (matgrass swards). The biodiversity in this landscape is declining with increased availability of nitrogen as a major cause. In addition, fragmentation and isolation have emerged as major bottlenecks.

The project studied measures to reduce habitat fragmentation and investigated possibilities to restore unimproved downland on former arable land. ...

- Eurasian Dry Grassland Group: edgg.org
- European Heathland Working Group: contact Geert.Deblust@inbo.be
- Foundation for European Forest Research: www.fefr.org/portal
- European Forest Institute: www.efi.int
- Wild Europe: www.wildeurope.org
- Rewilding Europe: rewildingeurope.com
- European High Nature Value Farming Network: www.hnvlink.eu
- Coastal & Marine Union: www.eucc.net

I.6.3 Other knowledge platforms

Endangered Landscapes Programme: www.conservationevidence.com and www.restorationevidence.org

LIFE-Nature: ec.europa.eu/environment/archives/life/publications/lifepublications/lifefocus/nat.htm

Natura2000 Communication Platform: ec.europa.eu/environment/nature/natura2000/platform/knowledge_exchange

European Nature Information System (EUNIS): eunis.eea.europa.eu

Biodiversity Information System for Europe (BISE): biodiversity.europa.eu

Eionet Portal: www.eionet.europa.eu/etcs/etc-bd

Ramsar Convention: ramsar.org/resources/ramsar-sites-management-toolkit

Water Information System for Europe (WISE): water.europa.eu

Agreement on the Conservation of African-Eurasian Migratory Waterbirds: www.unep-aewa.org

Flemish Nature Information System: www.ecopedia.be (in Dutch)

... The study demonstrates that it is possible to recreate species-rich downland on improved grassland sites. It is important to investigate the soil chemistry, variation in soil type and presence of special features and to adapt the restoration plan in accordance with these findings.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CHAPTER B.II.

Green Infrastructure and Network Coherence

Theo van der Sluis & Rob Jongman

II.1 Introduction

This chapter on 'network coherence' discusses the 'network of protected areas' and its physical connections in the landscape. No natural or protected area stands on its own: natural areas are always somehow connected with surrounding areas, through physical connections (corridors) and species which move between areas. This is often called an 'ecological network'.

An ecological network consists of habitat patches for a population of a particular species that exchanges individuals by dispersal.

The concept of 'network coherence' stems from landscape ecology, and is known by various terms, like landscape connectivity, a concept much used in ecological networks, and more recently the wider concept of Green Infrastructure. These aspects are briefly explained and an overview is provided of the approaches in many European countries, as well as how the concept is embedded in national or regional policies and strategies. Some inspiring examples are presented on how these strategies have been developed at a local or regional level, to improve connectivity for specific habitats and species.

II.1.1 The concept of network coherence and landscape connectivity

Biological diversity is highly dependent on the quality, quantity, and spatial cohesion of natural areas. If wildlife is spread over a large area in small numbers, and if the remaining areas are too small, sooner or later wildlife species will disappear.

An ecological network consists of habitat patches for a population of a particular species that exchanges individuals by dispersal.

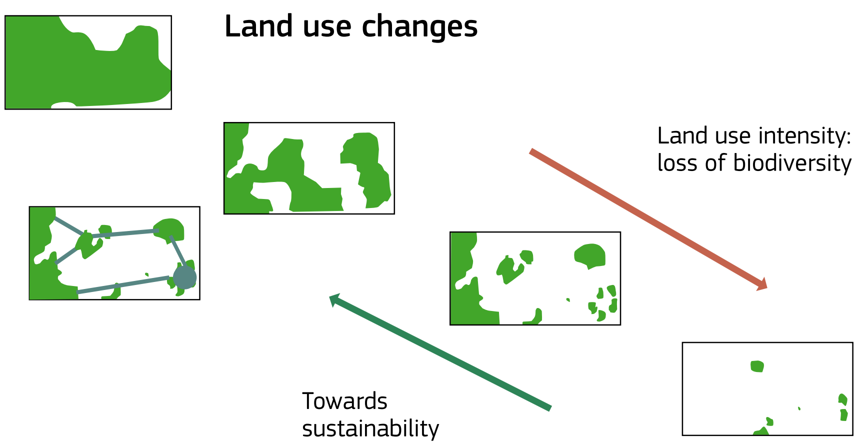


Figure II.1
The concept of landscape fragmentation: with increasing land use intensity, natural habitats are lost resulting in a fragmented landscape with very limited habitat.
(*Van der Sluis et al., 2011*)

Due to intensive human use, Europe´s habitats are 'fragmented' and sometimes lost. Figure I.1 illustrates the process of fragmentation of natural areas. Extensive natural areas (upper scheme) have been changed over time by human activity such as deforestation. The suitable land surface is decreased, or broken up into small habitat patches (lower scheme "Figure II.1" on page 25). Due to the fragmentation of their habitat, many species in Western Europe have already disappeared or may disappear from several regions in the future. As natural areas are fragmented, only small populations of species can survive in the small and isolated habitat patches. Whether species survive or not, often depends on a fragile balance. For example a number of bad years, an epidemic disease or a coincidence may result in the extinction of a species*. However, good landscape connectivity will give species a better chance of survival in the long term. Moreover, the impact of climate change, which may result in species and habitats moving north in Europe, may be less severe if landscapes are well connected.

Landscape fragmentation severely affects the abundance of species. An answer to this problem is improving network coherence, that is, strengthening of the ecological network.

Network coherence is important in allowing for repopulating or restocking of small areas and habitats, which is why areas need to be connected to the remaining core areas for wildlife in the vicinity (*Jongman et al., 2011; Snep & Ottburg, 2008*). For birds, this means that the distance from source areas to their habitat is less than the normal distance they might cover when flying. For non-flying animals it might mean that a physical connection is required that functions as a corridor, e.g. woodlands, streams, rivers, natural grasslands, and so forth (*Van der Grift et al., 2013*; *Van der Sluis et al., 2004*).

The **connectivity of the landscape for a species depends on the mobility of a species and the type of the available habitat and its configuration in the landscape. Likewise, for habitats it depends on the natural configuration of habitats, and inherent properties of the particular habitat**. Corridors are very important for certain species. The connectivity is very much defined by species characteristics: range, habitat choice, dispersal distance, carrying capacity. These species-specific characteristics cannot be changed. The landscape itself can to some extent be adjusted. Also, each species requires a different type of corridor, and corridor types can be linear, linear with nodes, stepping stones, or landscape mosaics.

In addition to the ecological need for network coherence, there are also formal requirements in the nature directives, in particular Article 10 of the Habitats Directive. This deals with the coherence of the Natura 2000 network and the management of nature outside the network. The legal aspects are discussed in paragraph II.1.2 Policy and legislation.

The various concepts have been presented in guidelines such as the 'European corridors: strategies for corridor development for target species' (*Van der Sluis et al., 2004*) but also in various brochures, papers and articles (*Opermanis et al., 2011*; *Vos et al., 2001*).

Options to improve landscape coherence

Basically, the options for improvement of landscape coherence or landscape connectivity are:

- Through development or improvement of corridors
- Improvement may entail widening, adapting the vegetation to provide more cover for species, establishing water points or stepping stones etc.
- Enlargement of core areas, conservation areas, by enlargement and improvement of habitat
- Improvement of the 'matrix', the surrounding landscape, e.g. through stimulation of low-intensity farming, reduced use of agro-chemicals, or more natural forest management for forest corridors, better conservation of the riverine vegetation and avoiding expansion of human settlement.

Finally, one should be aware that a corridor for one species can be a barrier for another. A forest corridor, or forest area which is a connection or habitat for a forest species, can be a barrier for certain butterfly species or meadow birds that avoid forested areas. Therefore, one cannot speak of 'an' ecological network, since it is species-specific. Development or improvement of landscape or network coherence is always a matter of choices, certain species groups that measures are aimed at or intended for.

What are ecological networks

An ecological network is a system of areas which are connected via ecological links or physical links. The ecological network usually consists of 'core areas' (protected or not), corridors, buffer zones and in some cases nature restoration areas. A pivotal role in ensuring spatial cohesion of the network is therefore played by corridors. Together with so-called 'core areas' corridors form essential components of ecological networks. The network coherence is an essential part of various strategies for ecological landscape planning.

Ecological networks can be especially beneficial for large herbivores like the red deer and gazelle, or for top predators like the wolf, leopard, lynx and otter. Corridors for large animals will also benefit many small organisms as a result of improvements in spatial cohesion and expansion of natural habitats.

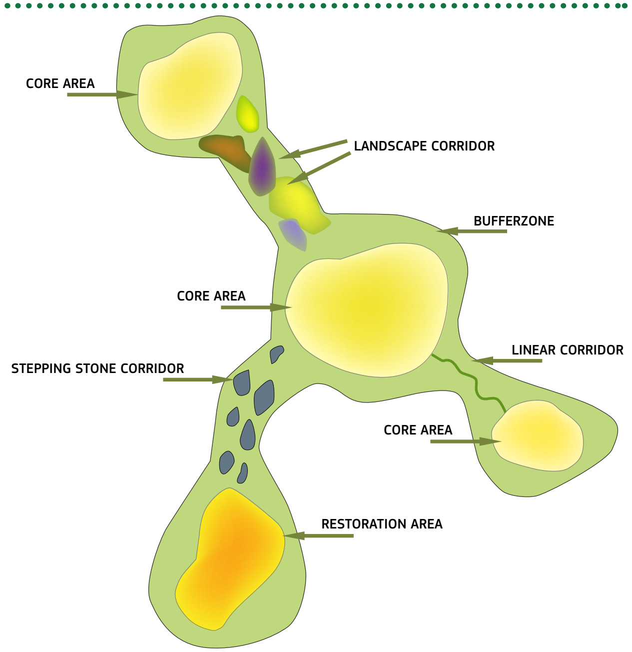


Figure II.2
Schematic overview of an ecological network.
(after *Bouwma, Jongman & Butovsky, 2002*)

What is Green Infrastructure

In the United States, the network concept was developed and referred to as 'greenways' (*Ahern, 1995*). Recently, the term coined in EU policies for the same concept is 'green infrastructures'. By its nature, Green Infrastructure has a wider set of aims, or ambitions than ecological networks. Green Infrastructure (GI) is a concept, not a set of rules, and there are many interpretations of Green Infrastructure. GI is a spatial and functional structure delivering nature benefits to people. The focus is on multifunctional use, whereby natural areas can contribute to biodiversity conservation and other environmental functions.

Green Infrastructure is an approach '... that brings together both the need for strategic planning of green and open spaces and the science of ecosystem services. It promotes the multifunctional nature of space and the benefits that appropriate management approaches can deliver. It recognises the need to plan land use for specific purposes such as farming, nature protection and development but also provides the tools and methods to identify needs and opportunities to enhance the environment and its functions' (*John et al., 2019*).

The three key GI principles are connectivity, multifunctionality and spatial planning. A recent publication provides guidance on data, methods and tools to implement GI (*Estreguil et al., 2019*). How to create a strategic design of a well-connected, multi-functional, and cross-border GI.

The three key GI principles are connectivity, multifunctionality and spatial planning.

GI mapping has been demonstrated to enhance nature protection and biodiversity beyond protected areas, to deliver ecosystem services such as climate change mitigation and recreation, to prioritise measures for defragmentation and restoration in the agri-environment and regional development context, and to find land allocation trade-offs and possible scenarios involving all sectors.

II.1.2 Policy and legislation

The development of ecological networks and corridors is recognized as a positive policy for promoting nature conservation both at European and global levels (*Jongman et al., 2011*).

The Bern Convention aims at conserving wild flora and fauna and their natural habitats. As part of its work under the Bern Convention the Council of Europe launched the so called Emerald Network, an ecological network of Areas of Special Conservation Interest. To fulfil its obligations arising from the Bern Convention and to realise the Emerald Network the European Union set up the Habitats Directive (Council Directive 92/43/EEC) and subsequently the Natura 2000 network.

Article 10 of the Habitats Directive is an important instrument to improve, where necessary, the ecological coherence within the context of the Directive and as a part of the national and regional ecological networks. Article 3.3 and 10 explicitly refer to connectivity in the wider landscape. A long-term target for the implementation of Article 10 should be to identify the relationship between Favourable Conservation Status and connectivity. In this context species and habitats occurring outside Natura 2000 sites also need to be considered.

Green Infrastructure is of more recent date, and forms an important part of the European policy agenda. It is specifically mentioned in target 2, Action 6 of the Biodiversity strategy, *Our life insurance, our natural capital: an EU Biodiversity Strategy to 2020* (*European Commission, 2011*). Target 2 of the Strategy mentions: '*By 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and restoring at least 15% of degraded ecosystems*'. Action 6 mentions: Set priorities to restore and promote the use of green infrastructure. The Commission developed a Green Infrastructure Strategy to promote the deployment of green infrastructure in the EU in urban and rural areas, including through incentives to encourage upfront investments in green infrastructure projects and the maintenance of ecosystem services.

The EU biodiversity strategy 2030 highlights the importance of a coherent Trans-European Nature network, and the need " ...to set up ecological corridors to prevent genetic isolation, allow for species migration, and maintain and enhance healthy ecosystems" (*European Commission, 2020*). The Strategy also mentions the ambition to unlock at least 20 billion a year for investing in Natura 2000 and green infrastructure.

The following table gives an overview of the legal aspects of GI, and how it is protected in national legislation in central Europe (*John et al., 2019*).

The Birds and Habitats Directive art. 10

Article 10 of the Directive states: *Member States shall endeavour, where they consider it necessary, in their land-use planning and development policies and, in particular, with a view to improving the ecological coherence of the Natura 2000 network, to encourage the management of features of the landscape which are of major importance for wild fauna and flora.*

Such features are those which, by virtue of their linear and continuous structure (such as rivers with their banks or the traditional systems for marking field boundaries) or their function as stepping stones (such as ponds or small woods), are essential for the migration, dispersal and genetic exchange of wild species.

In addition, Article 3 mentions under 3): *Where they consider it necessary, Member States shall endeavour to improve the ecological coherence of Natura 2000 by maintaining, and where appropriate developing, features of the landscape which are of major importance for wild fauna and flora, as referred to in Article 10.*

Furthermore, Article 4 of the Birds Directive states: *Member States shall take similar measures for regularly occurring migratory species ..., bearing in mind their need for protection in the geographical sea and land area where this Directive applies, as regards their breeding, moulting and wintering areas and staging posts along their migration routes.*

Regulation Topic	Global or regional international regulations	EU	AT	AT Lower Austria	CZ	DE	DE Saxony	IT	IT Piedmont	PL
Green Infrastructure										
Green Infrastructure		GI	GI	GI	GI	GI				GI
Protection of Nature, Biodiversity and Landscape										
Nature and Biodiversity Protection (in general)				GI	GI	GI	GI			GI
Biodiversity Protection	GI	GI	GI		GI	GI	GI	GI	GI	
Species Protection	GI	GI		GI	GI	GI	GI	GI		GI
Invasive Species Management		F		F	F	F	F	F		F
Protection of areas/habitats	GI	GI		GI	GI	GI	GI	GI	GI	GI
Landscape Protection		GI		GI	GI	GI	GI	GI	GI	GI
Protection of Cultural and Natural Heritage	GI	GI					GI		GI	GI
Environmental Protection										
Prevention of harmfull Effects on the Environment (in general)		F		F	F	F GI		F		F
Environmental Liability		F	F	F	F	F		F		F
Environmental Assessment (EIA/SEA)	F	F	F		F	F	F	F	F	
Water Protection	GI	GI F	GI		GI	GI F	GI F	GI F	F	GI
Air and Climate Protection		F	F		F	F	F			F
Soil Protection		F		F	F	F	F	F	F	F
Economy and Sustainable Development										
Agriculture		GI		GI	GI	GI	GI			GI
Forestry		GI	GI	GI	GI	GI	GI	GI	GI	GI
Hunting and Fishing		GI F		GI F	GI F	GI F	GI F	F	GI F	GI F
Tourism and Recreation	GI	GI		GI	GI	GI	GI	GI		
Energy		F	F		F	F	F			F
Sustainable Development		F	F		F	F	F	F		F
Spatial Planning										
Regional and Local Planning		F		F	GI F	GI F	GI F		GI F	GI F
Urban Planning		GI		F	GI	GI	GI	GI	GI	GI
Sectoral Planning		F	GI F	F	F	F	F		GI F	GI F
Access to Information on the Environment and Public Participation	F	F	F	F	F	F	F	F	F	F

Table II.1

Protection of Green Infrastructure (**GI**) or its Functionality (**F**) by regulations, laws and policies at different levels. (*John et al., 2019*)

EU *European Union*
AT *Austria*
CZ *Czech Republic*
DE *Germany*
IT *Italy*
PL *Poland*

After the 1992 global summit in Rio de Janeiro, where the Convention for Biological Diversity (CBD) was agreed upon, the **Council of Europe** initiated the Pan European Biological and Landscape Diversity Strategy (PEBLDS), making the planning of the Pan European Ecological Network at European and national levels its first objective. Next to the European Birds directive, the Habitats Directive and PEBLDS, there are several global and European conventions that are important for Connectivity conservation. These are the CBD, the Wetlands Convention, the Bonn Convention on migratory species and the Bern Convention, on which the Habitats Directive is based.

II.2 Ecological networks and GI at national level

II.2.1 Methods and approaches

Political support for investing in conservation of biodiversity, including connectivity, has generally increased over time in Europe. Planning landscape connectivity and ecological networks is generally accepted in Europe, but in practice carried out in different ways due to political, geographical and economic priorities. Germany, Austria, Italy and Spain are **decentralized federal countries**, while countries such as Denmark, the Netherlands, Portugal and the Czech Republic are more **centralized**.

Political support for investing in conservation of biodiversity, including connectivity, has generally increased over time in Europe. Building road- and railway crossing structures for species and habitats' connectivity depends on funding from the transport sector at European and national levels, and joint planning by transport agencies and conservation planners. **The European Commission promotes environmentally-friendly infrastructure building through its co-funding programmes so that wildlife bridges are often included in road projects**. Funding for connectivity conservation is partly provided by the European Commission, partly by national or regional governments and funds. Funding is project-driven and initiated by national and regional governments or NGOs. Cooperation depends on willingness and priorities across borders.

II.2.2 Regional approaches for Network coherence

This paragraph summarizes regional approaches. Detailed descriptions of how national policies evolved over time can be found in the detailed country descriptions, which are accessed through the links in the text.

Federal states are not all organised in the same way. In some countries (Austria, Belgium, Spain, UK) all power in the field of Nature Conservation is devolved to the lower 'regions', or 'Länder'. This can cause differences between regions within these countries. It can also be a source of complex negotiations as the national state is the point of reference for the European Union, but in some cases without power to carry out the requests from the European Union without internal coordination. In Germany the framework legislation gives the Federation (Bund) the power to make guidelines; for nature conservation, guidelines have been made in close cooperation with the member states. This means that a national approach can only be reached through negotiation and agreement between regions. In Italy tasks and responsibilities are devided between the state, the regions and provinces. In Austria the federation has no power in this field.

Unitary states maintain the formal responsibilities for nature conservation at the national level, although it is also possible that part of the main executive and the implementation of tasks have been delegated to the regions. In most countries where national responsibility is dominant, the Ministry of Environment is responsible. In a number of cases, however the Ministry of Agriculture is responsible, such as in the Netherlands and Greece. In Greece the Ministry of Agriculture is responsible for the management of National Parks and all forested areas in general, species protection, the supervision of issues on fisheries, hunting, forestry, agriculture, genetic resources, ex situ plant conservation and domestic animals.

Former Soviet Union countries

National connectivity plans had already been written in Eastern Europe in former Czechoslovakia and the former Soviet Union, including the Baltic states, with the general objective of landscape ecological stability (*Mander et al., 1988*; *Bucek et al., 1986*; *Bucek et al., 1996*). For all three Baltic countries, ecological networks have been developed at national, regional and local scale. They have been published together under coordination of the IUCN office for Central Europe.

The approach is illustrated by the case of the conservation history for Estonia. **The principles of the ecological network were first applied in Estonia in the 1960s, when it was tried to regulate the use and planning of natural resources**. In the years 1979–81 the state ordered "The outline for the protecting and sustainable use of Estonian natural resources". The Physical Geography Department of the University of Tartu developed the idea of the ecological network of Estonia, the so-called system of ecologically compensatory areas. These areas were handled as parts of a cultural landscape that mitigated the anthropogenic influence on the landscape. The map of Estonian compensatory areas with the explanatory letter was ratified as a basis for planning and developmental action until the year 2005.

Determining the green network was one of the chapters in national planning "Estonia – vision 2010". It suggested that core areas should be determined on the basis of at least two aspects: area and value. Natural regions comprising compact natural territories with an area of at least 100 km² were defined as core areas of international importance. 'Compact' regions with a ter-

Estonia 2010 Green Network

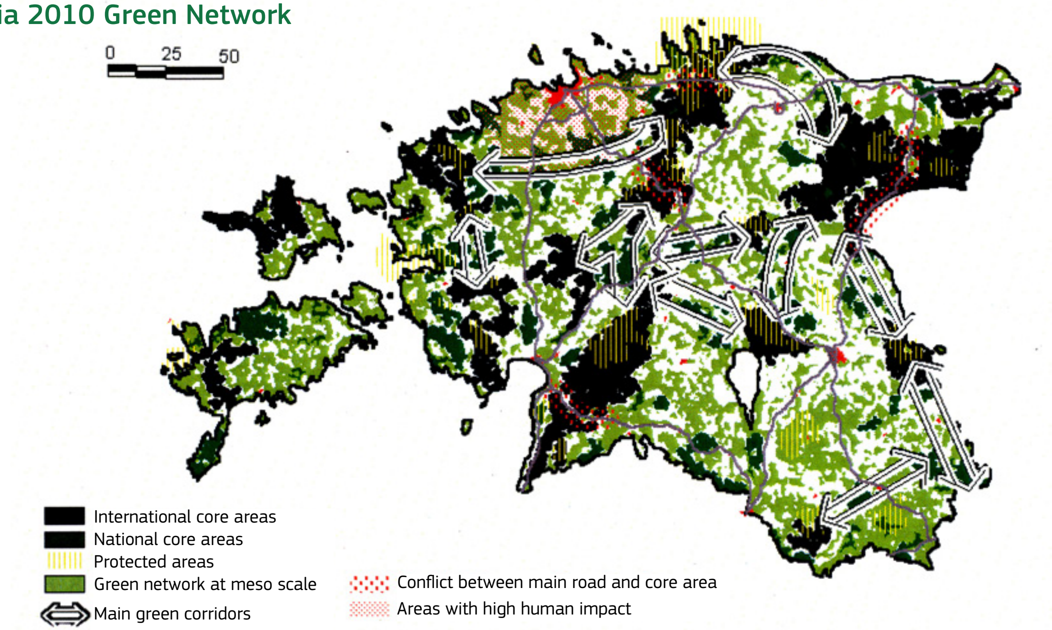


Figure II.3
Network of ecologically compensating areas of Estonia. (*Mander et al., 2003*)

ritory of at least 15 km² are defined as core areas of national importance. As areas of national importance are situated in between the areas of international importance, it is possible to mark the most important 'green corridors' of the network, which constitute convenient dispersal routes for species between the core areas.

Networks of ecologically compensating areas should fulfil the following main ecological and socio-economic functions in landscapes: biodiversity, material and energy flows, socio-economic development (e.g. recreation) and cultural heritage.

Former Eastern Bloc countries of Central Europe

The concept of ecological networks and its application in the planning practice in former Czechoslovakia and later in Slovakia as well as in the Czech Republic was formulated as the territorial system of ecological stability TSES. The main purpose of the establishment of the ecological networks approach is the preservation of spatial ecological stability of the landscape. The concept of TSES started in 1970 and was a pioneering ecological network at national, regional and local levels. It was one of the first comprehensive concepts of this kind *(Miklos et al., 2011)*. It represents a hierarchical connectivity concept of ecological core areas (biocentres) of different importance connected by biocorridors.

TSES projects in Slovakia were carried out top-down, from the General Plan of supra-regional TSES, through regional to local TSES. Following the General Plan, the National Ecological Network (NECONET) was set up based on the concept of the European Ecological Network and building on principles of the Dutch National Ecological Network. The regional TSES (RTSES) have been developed in the years 1993–1995 for all 38 regions at a scale of 1:50,000. When Slovakia joined the EU, the European system of Natura 2000 was integrated in the TSES projects.

Also in the Czech Republic, landscape fragmentation is an issue of importance and maintenance of corridors and landscape elements is an important aspect of the Czech nature conservation policy. Not having been part of the nature policy in the 1980s, they have been integrated into the TSES concept in the 1990s as Significant Elements of the Landscape (SLE) and legally recognised (Act 114/1992). They are considered to be the "skeleton of ecological stability in the landscape" and are partly legally protected.

Bulgaria has incorporated the ecological network concept in the Biological Diversity Act. This Act regulates the protection of habitats, of species of plants and animals and their biotopes. It introduces the requirements of the Habitats and the Birds Directives, focused on preservation of habitat types and biotopes of plant and animal species. The Act on the Biological Diversity envisages the establishment of National Ecological Network, consisting of three elements – protected zones, protected areas and buffer zones. The rapidly growing road network in Bulgaria, initiated by EU strategies to construct Pan-European Transport Corridors, results in increasing conflicts with biodiversity objectives and the aim of a coherent Natura 2000 network. Therefore, one of the big challenges at present is the mitigation of the fragmentation of the landscape by roads and railways.

Unitary states

In Western European countries such as Denmark and the Netherlands, spatial planning for connectivity conservation is regulated in spatial planning and nature conservation legislation (*Jongman et al., 2004*; *Van der Sluis et al., 2012*).

The national ecological network in the Netherlands stems from 1990 (Ministry of Agriculture, Nature Management and Fisheries, 1990). The Nature Policy Plan (*Natuurbeleidsplan*) presented the National Ecological Network (*Ecologische Hoofdstructuur*, NEN). The aim of NEN is to develop a coherent network of natural areas (core areas and nature development areas) that are connected by ecological corridors. With this concept of NEN, the government launched a new approach to nature conservation, replacing the traditional protection of natural areas in their original status with an active form of protection and nature development, setting clear priorities in a wider (inter)national context.

2012, during the economic crisis, re-orientation and decentralisation of the national nature policy took place. The original plan of the NEN was abandoned and aims were reduced to more or less the area that had been realised at that moment. Coordination between national and provincial authorities was needed for realizing necessary connecting measures for provincial roads for an optimal return on investments. After the crisis, a renewed effort was made to speed up the process of landscape defragmentation with the Netherlands Nature Network with extra funds.

In the Netherlands, the owner and manager of transportation infrastructure is responsible for financing and implementing all ecopassages (bridges and culverts). This is the main reason why ecoducts and culverts were not implemented in the 1990s.

Figure II.5
National Ecological Network of the Netherlands.

In 2007, the green and blue infrastructure (Trame vert et blue, TVB) was launched in France. The TVB aims to maintain and restore a green-blue network, to reduce habitat loss and fragmentation and to integrate biodiversity into urban planning, in line with the EU Nature and Water Directives. The green and blue infrastructure takes into account the ecological functioning of ecosystems and species in land use planning and focuses on 'common' biodiversity. The TVB consists of five subnetworks, e.g. the wooded subnetwork and the wetland subnetwork. Based on national guidelines, regional and local networks are being developed. Regional Ecological Networks (REN) were designed with several methods freely chosen by the regions (e.g. least-cost path). Barriers to species movements (roads, dams, other infrastructure) have been identified and plans for actions formulated to preserve or restore the core areas and corridors.

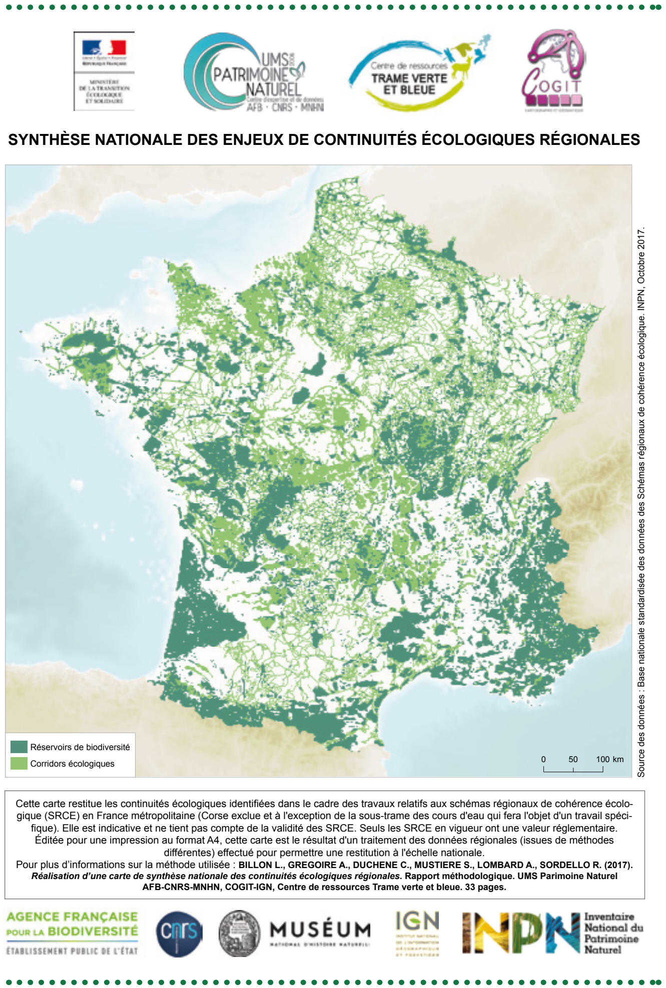


Figure II.5
French 'Trame vert-et-bleu' or green-blue network. (source: Romain Sordello)

Decentralized governments (federal states)

In contrast, in federal states like Spain, Germany, Italy, Austria and Belgium, regional governments are given wide latitude in spatial planning, with some guidance from federal statutes.

In 2007, the Spanish Parliament adopted a new Nature Conservation Act (Ley 42/2007) which includes ecological networks and ecological corridors. The Act defines ecological corridors as corridors connecting natural sites of special importance for wild flora and fauna, allowing genetic exchange between otherwise separated populations. Article 17 defines ecological networks as networks of sites of high natural value which allow the movement of flora and fauna species. It also specifies that nature management plans have to contribute to connectivity conservation and restoring corridors. It mentions as important corridors: river courses, drove roads (cañadas) and mountain ranges.

The different regions implement this Act in their own way, since there is regional autonomy. At present there are three regions that have developed ecological network plans: Cataluña, Basque Country and Madrid. In 1992 in Cataluña, the plan for spaces of natural interest (PEIN) was created, which was the first coherent plan that delimits and establishes a conservation system for the basic protection of representative natural spaces in accordance with their scientific,

Figure II.6

Very particular for Spain are the drove roads (cañadas) for sheep, which form part of the ecological network. Here the Cañada real de Segovia with grazing cattle. © Rob Jongman

ecological, landscape and cultural importance. Studies were done on the improvement of the ecological network, e.g. with the model LARCH (*Franz et al., 2011*). Later in the Basque country (2005) and Madrid (2010) ecological networks were designed. However, the concept has not yet been implemented. One of the important causes of delays seems to be the lack of resources. Another problem is that regional planning is focusing on urban areas and town planning, and that land use planning for rural areas is lacking.

NGOs are very important in pushing developments in Spain. For instance the Fundación Oso Pardo which is developing with EU-Life+ funds connectivity for populations of the brown bear. There are several associations involved in the use and protection of the Spanish cañadas as well as groups dedicated to specific species, such as the Spanish Ornithological Society (Sociedad Española de Ornitología).

The German federal nature conservation law, BNG, dates back to 1976 and its last revision is from 2009. One of the major tasks in a federal state like Germany with devolved responsibility for nature conservation is the integration of the state networks into a national ecological network. States and federation work together on this under coordination of the Federal Nature Conservation Agency (BfN). Through landscape planning, nature conservation criteria can be taken into account in planning and administrative procedures and the ecological network be realised.

Defragmentation is an important issue in Germany. Work on defragmentation is organised by the states in cooperation with the Federal Nature Conservation Agency, consultants and universities, such as the university of Kiel and the university of Kassel. In the planning and realisation of linear infrastructures (construction of new roads and expansion of roads, railways, canals) the existing ecological interconnectedness is to be preserved in such a way that colonization and repopulation of habitats by naturally-occurring species can take place in sufficient numbers. Depending on the affected habitats and species, special measures can then be planned to preserve these network relationships.

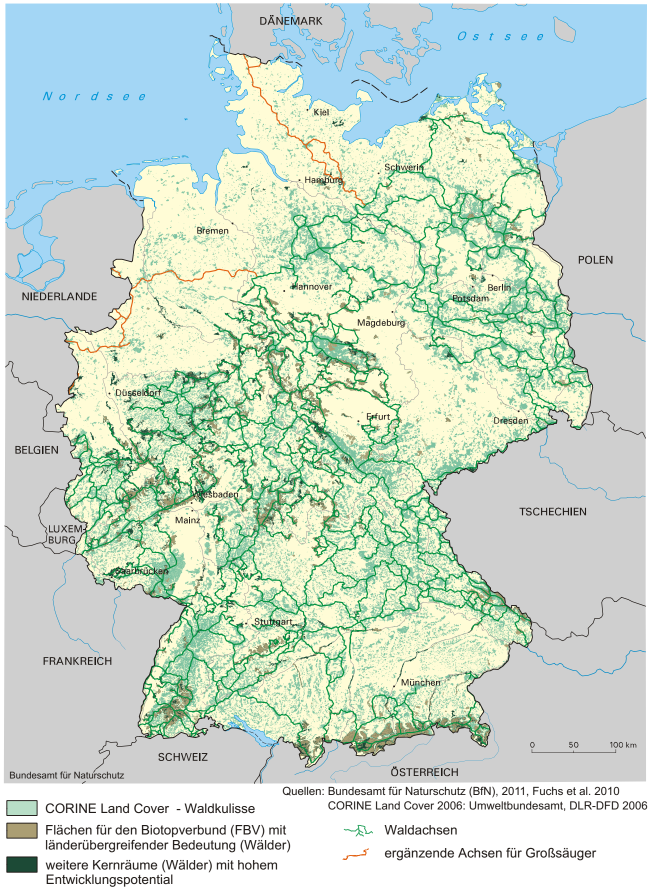


Figure II.7
National important corridors and core areas for forest ecosystems.
(*Fuchs et al., 2016*)

In Italy, there are twenty-one regions with an increasing autonomy. The state generally has a coordinating role. Each region has to produce regional legislation and often provinces and municipalities issue local regulations. State, regions, provinces, and municipalities all have responsibilities in managing parks and reserves at national, regional, provincial and municipal levels. This means that regions draft regional scale framework laws and regulations; local authorities such as provinces and municipalities define rules for application. This situation regarding task sharing allows much freedom for the different authorities to develop their own vision of nature conservation and the development of ecological networks.

Territorial fragmentation and ecological connectivity have been studied and addressed within regional authorities as well as within research institutes and universities. In 2003, ISPRA published guidelines for the management of functional ecological connection areas, containing practical information on the issues of conservation, planning and management of ecological corridors. The LARCH model was used (*Estreguil et al., 2019*) to analyse the landscape and territory, and with habitat modelling of target species an ecological network was proposed and partly implemented through regional initiatives and initiatives with project funding from LIFE and regional authorities. Several regional networks were developed, e.g. through the LIFE-Econet projects such as for parts of Emilia Romagna (*Van der Sluis et al., 2001*; *Van Rooij et al., 2003*), Abruzzo (*Van der Grift & Van der Sluis, 2003*; *Van der Sluis et al., 2003*) and Umbria *(Van der Sluis & Pedroli, 2004*).

In Austria, there is no federal law establishing a framework for detailed nature conservation legislation by the Länder. Most of the connectivity restoration activities are carried out jointly by the states and NGOs such as the Alpen-Karpaten corridor and initiatives for stream restoration.

In Belgium, the Flemish government is leading the process of developing a Flemish Ecological Network. The Flemish Decree on Nature Conservation (1997) defines the Flemish Ecological Network with core areas and nature development areas (VEN) as well as Integrated Multi-functional and Supporting Network with nature corridors (IVON). A target for the VEN is to protect 125.000ha (9.3% of Flanders). The nature integration areas (IVON) are supposed to cover 150.000ha. The Flemish Decree on Physical Planning aims to incorporate nature conservation targets (VEN, IVON) into physical planning objectives. The provinces have the responsibility to realize ecological corridors. Approximately 14 years after the date that was set in the Nature Decree and eight years after the target year in the IVON, 3% (around 5,084ha) has been demarcated.

In the stage of realization of individual projects, informal cooperation with private stakeholders has to be established. This is partly done for the nature restructuring projects where landowners, farmers, hunters etc. are involved and persuaded into a 'nature-friendly' management. For the realization of the corridors, cooperation on a voluntary base is the rule. The negotiations between sectors and their legal bodies on the level of the administration in charge (nature conservation, agriculture and forestry) are time consuming.

II.3 Implementation of GI at site/regional level

II.3.1 Methods and approaches

In some cases very simple **fragmentation indices** are used to design measures for defragmentation, e.g. the use of Fragstats (*Mcgarigal et al., 2002*). These are generally not very suitable for ecological network or GI purposes, since they are too generic and the output of indices mostly says something about the map quality. Results cannot be generalized for planning.

The **functionality of the landscapes for species** is an essential aspect for species' survival. Various model approaches analyse the dynamics of species populations living in ecological networks. Such dynamics are determined by (a) the number of individuals that on average live in the network (carrying capacity), which is a function of habitat quality and network area, and (b) the spread or dispersal of individuals across the network (connectivity), which is a function of the network density and the permeability of the landscape matrix in which the network is embedded (*Opdam et al., 2002*).

To perform a landscape analysis of sustainability of (meta)populations the model LARCH was developed. The parameters were calibrated for species and ecosystems in the Netherlands (*Foppen et al., 1999*; *Verboom et al., 2001*; *Verboom & Pouwels, 2004*). The LARCH model was applied in many different countries and regions where case parameters were adjusted according to the local conditions, for example in North-West Europe, Poland, the Meuse Basin, the river Rhine, Abruzzo, Umbria and Emilia Romagna regions in Italy, Catalunya in Spain, Israel and Ukraine (*Franz et al., 2013*; *Franz et al., 2011*; *Geilen et al., 2001*; *Groot Bruinderink et al., 2003*; *Pungetti & Van der Sluis, 2002*; *Van der Sluis et al., 2007*; *Van der Sluis & Van Eupen, 2013*).

The **assessment of corridors** requires specific tools or models, which define how well-connected the landscape is. Currently, **there are no dedicated standalone tools that can be used to assess the spatial distribution of GI**. Applied GI projects are based on a compilation of spatial and analytical tools that have been developed for quantifying and analysing habitat aspects of interest to GI deployment. Instead, practitioners must be able to use standard GIs and environmental systems analysis tools (*Estreguil et al., 2019*).

Specific methods or tools exist such as QuickScan (*Van der Sluis et al., 2015*; *Verweij et al., 2016*), as well as free software packages, such as GuidosToolbox, Linkage Mapper, or Conefor (*Estreguil et al., 2019*; *Saura & Torne, 2009*). Free tools now available enable assessment at multiple scales, i.e. from local to regional, but also at European and global scales, due to increased computational capacities.

Network coherence is often addressed on the basis of:

» assessment of landscape fragmentation, through indices
» assessment of functionality of the landscape for particular species or ecosystems
» assessment of corridors

II.3.2 Financial instruments

Financing of measures for Green Infrastructure is possible through the Natural Capital Financing facility. This facility is in particular meant to halt the loss of biodiversity and adapt to climate change. To do so, the European Investment Bank (EIB) and the European Commission have partnered to create the Natural Capital Financing Facility (NCFF), a financial instrument that supports projects delivering on biodiversity and climate adaptation through tailored loans and investments, backed by an EU guarantee.

II.3.3 Example studies for improving network coherence

A number of examples based on LIFE or Interreg projects are presented on how measures were prepared for improvement of the coherence of habitats, as well as for specific species. The species' habitats described are selected based on their need for spatial coherence; various criteria were used to define priority habitats that are in unfavourable conservation status and require landscape coherence (*Van der Sluis & Bouwma, 2019*). The descriptions below are largely based on the examples in this study (with permission of ETC-BD). The criteria also include the potential for habitat restoration. The selected species are flagship species, which may stimulate conservation and benefit the ecosystem and a wider set of species.

Habitats and network cohesion

a. Boreal Baltic coastal meadows (1630*)

Ecology and distribution
The 'Boreal Baltic coastal meadows' are characterized by low-growing plant communities. They occur in the geolittoral zone and are sometimes interspersed with salt patches. Characteristically the vegetation occurs in distinct zones, with saline vegetation closest to the sea. The salinity is low since tide hardly exists, but they can be affected by land upheaval.

The habitat is widespread along the Baltic coast of Estonia, Finland and Sweden, rare in Latvia and absent from Lithuania. Estonia reported the largest habitat area. Of the approximately 190 km² of this habitat in the Boreal region, about 78% is included in Natura 2000 sites.

Land use in this zone consisted historically mostly of grazing and mowing, which resulted in a gradual expansion of the habitat, keeping the vegetation low and open and rich in vascular plants.

Important bird species which depend on this habitat type and adjoining lagoons (Habitat 1150) are Birds Directive Annex I species Eurasian bittern (*Botaurus stellaris*), as well as several Annex II species, including Black-tailed godwit (*Limosa limosa*), Common redshank (*Tringa totanus*), Mute swan (*Cygnus olor*), Eurasian coot (*Fulica atra*), Northern lapwing (*Vanellus vanellus*) and Common snipe (*Gallinago gallinago*). Also the Dunlin (*Calidris alpinas schinzii*), Ruff (*Philomacus pugnax*) and other meadow wader species breed here, and a grassland passerine community

The LIFE program

An important source of funding for improving Green Infrastructure and network coherence is the LIFE-Nature program. In the past the program has been funding activities related to improving the connectivity for large carnivores, removing barriers for raptors migration, ensuring river connectivity, transnational planning etcetera. The program will continue in the period 2021–27 with an increase of almost €2 billion from the present LIFE program.

In particular the following LIFE programs might be relevant, but check the ec.europa.eu/easme/en/life for up-to-date information:

- **Regular LIFE+ Nature & biodiversity**: funds projects and local activities from various partner organisations and NGOs;
- **Integrated projects**: implements e.g. the Priority Action Frameworks and River Basin Management plans. Projects are large scale; payment of complementary actions with additional co-funding; requires involvement of stakeholders;
- **Strategic Nature Projects (SNaPs)**: Mainstreaming of nature and biodiversity into other policies and programmes through coherent programmes of actions in the Member States, including institutional support. Beneficiaries are the competent nature/biodiversity authorities, in partnership with relevant stakeholders (there is also a possibility of funding for transborder SNaPs).

is present. A large number of waders of different species, as well as migrating geese and other waterfowl are present during passing migration (*Rūsiņa et al, 2017*). In moister areas, large sedge tussocks are preserved, which are important for birds. This also indicates that the scale of the area and variety of habitats defines the completeness of bird assemblages (*Rūsiņa et al., 2017*).

Coastal meadows are valuable habitats for a large diversity of invertebrate species, in particular nectar-feeding species and grassland species associated with animal excrement. One of the few endemic insects found in Estonia, *Aeschna osiliensis*, is specifically associated with coastal meadows and other coastal habitats. Seaweed mounds and salinas are home to an unconventional community of predatory beetles. Shallow water bodies that appear in coastal meadows provide habitat for the rare large white-faced darter (*Leucorrhinia pectoralis*). In coastal meadows there are various dragonflies and species of *homoptera*, *auchenorrhyncha* and *heteroptera*. Areas with a long-standing grazing tradition feature sods generated by ant species of *Lasius* and *Myrmica*.

A number of examples based on LIFE or Interreg projects are presented below on how measures were prepared for improvement of the coherence of habitats, as well as for specific species:

- Boreal Baltic coastal meadows (1630*)
- Alpine rivers and their ligneous vegetation with *Myricaria germanica* (3230)
- Temporary Mediterranean ponds (3170*)
- European sturgeon/Beluga (*Huso Huso*) (HD App. V)
- Large copper (*Lycaena dispar*) (HD App. II, IV)
- Eurasian lynx (*Lynx lynx*) (HD App. II, IV)
- Stag beetle (*Lucanus cervus*) (HD App. II)

The flora of Baltic coastal meadows is very rich, e.g. in Estonia a total of 390 plants species have been found, which is 26% of all Estonian species. More than 20 protected plant species grow on coastal meadows, including many orchids: *Dactylorhiza ruthei*, Frog orchid (*Coeloglossum viride*), Fen orchid (*Liparis loeselii*), Baltic orchid (*Dactylorhiza baltica*), Blood-red dactylorhiza (*Dactylorhiza incarnata ssp. cruenta*), Early marsh orchid (*Dactylorhiza incarnata*), Musk orchid (*Herminium monorchis*), Marsh helleborine (*Epipactis palustris*), Early-purple orchid (*Orchis mascula*), Common spotted orchid (*Dactylorhiza fuchsii*), Military orchid (*Orchis militaris*), Fly orchid (*Ophrys insectifera*) and Fragrant orchid (*Gymnadenia conopsea*) (*Anonymous, 2011*).

Figure II.8
Coastal meadows at Väinamere, Natura 2000 site EE0040002 Estonia. © Theo van der Sluis

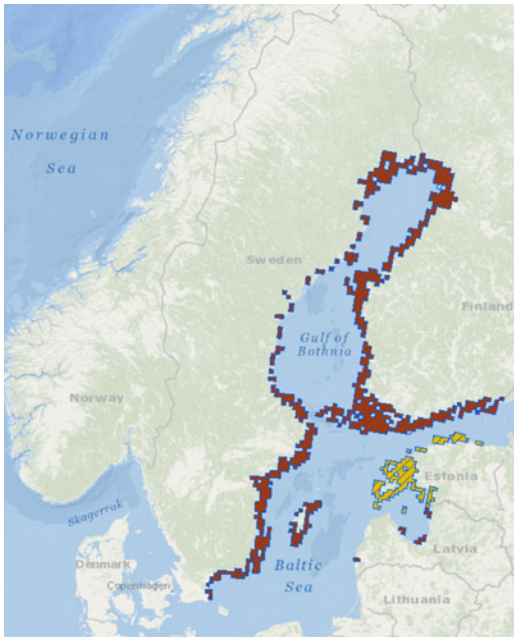
Proposed measures for GI
Appropriate management is the main proposed measure for maintenance of grasslands. Other proposed measures include the establishment of protected areas and improvement of legislation. The 'Natureship project (2009–2013)', was financed by the EU Central Baltic Interreg IV A Programme 2007–2013 and national funding providers. The project had two focus areas: "Water protection and coastal planning" and "Biodiversity and cultural landscapes". The project activities targeted coastal areas in Finland, Sweden and Estonia. A total of eleven organisations have been involved in project implementation. Lead partner was the Centre for Economic Development, Transport and the Environment in Southwest Finland, with other partners from Finland such as Metsähallitus, the University of Turku, municipalities, from Estonia the Environmental Board of Estonia and University of Tartu, and from Sweden the County of Gotland and Norrtälje Nature Conservation Foundation.

The goal of the project was to increase cooperation in habitat management and water protection in the Central Baltic operating area. The most important objective of the Natureship project was promoting interdisciplinary coastal planning following the principles of sustainable development. The aim of integrated coastal planning is to find solutions that will benefit all users of the area over the long term, taking natural values into account. It aims at finding the best cost-efficient methods for water protection and biodiversity and rating ecosystem services.

The project has promoted conservation cooperation between these areas and the exchange of experiences in habitat and species management. Ecosystem service thinking plays a role in the planning and implementation of management measures. The project aimed at finding win-win solutions that benefit all: nature, water protection, local farmers and entrepreneurs, as well as inhabitants. Special emphasis was placed on Natura 2000 areas.

Assessment of ecosystem services
Ecosystem services related to the proposed measures, as described above, are discussed in the chapter B.III and presented in Table III.3.

The Boreal Baltic coastal meadows are maintained through livestock herds which as part of agro-ecosystems have different outputs: reared animals and their resources, hay and possible other wildlife. **ES include the supply of nutrition and other renewable natural resources as well as occurrence of natural ecosystem processes, maintenance of water resources and circulation of nutrients**. The meadow ecosystem protects the coast against erosion, floods, and does some climate regulation, but the meadows also maintain pollinator populations and livestock will facilitate seed dispersal. **Ecosystem services also include recreational use of nature and the experiences obtained there**, as well as residential services, and inspirational services.



Conservation status
The conservation status of this habitat type is unfavourable-bad, based on the assessment in all Member States except Estonia which reported unfavourable-inadequate. The range is favourable in all countries, but other parameters are poor or bad for most of the region. In Sweden the bad situation is stable.

Problem
Inappropriate land use, particularly the abandonment of agricultural management (grazing and mowing) represents the major pressure to this habitat type. Abandonment of traditional management results in encroachment, which causes a decline in bird populations: grasslands smaller than 10 ha, will hold no waders and the passerine community may be incomplete. Pressures with less intensity are recreation, sport and water pollution. Finland informed that dredging/ removal of limnic sediments and dumping and depositing of dredged deposits are threats.

Figure II.9
Distribution of Baltic Coastal meadows.
(*Halada, Aronsson, & Evans, 2016*)

b. Alpine rivers and their ligneous vegetation with Myricaria germanica (3230)

Ecology and distribution
The habitat of Alpine rivers holds plant communities of low shrubby pioneers invading the herbaceous formations on gravel deposits rich in fine silt, of mountain and northern boreal streams with an alpine, summer-high flow regime. These deposits are usually dynamic, often being destroyed and recreated in floods. German tamarisk *Myricaria germanica* and Willow species *Salix spp.* are characteristic species of the '*Salici-Myricarietum*'.

The habitat type is typical for the Alpine biogeographical region, and most of the habitat is found in the Alps and Carpathians; an isolated occurrence is reported from northern Finland. The habitat usually occurs in small patches; the overall habitat area is quite small as well. In Germany, Poland, and Slovenia the entire national habitat area is located in Natura 2000 sites; in Austria and Finland a large part of the national habitat area is located in Natura 2000 sites.

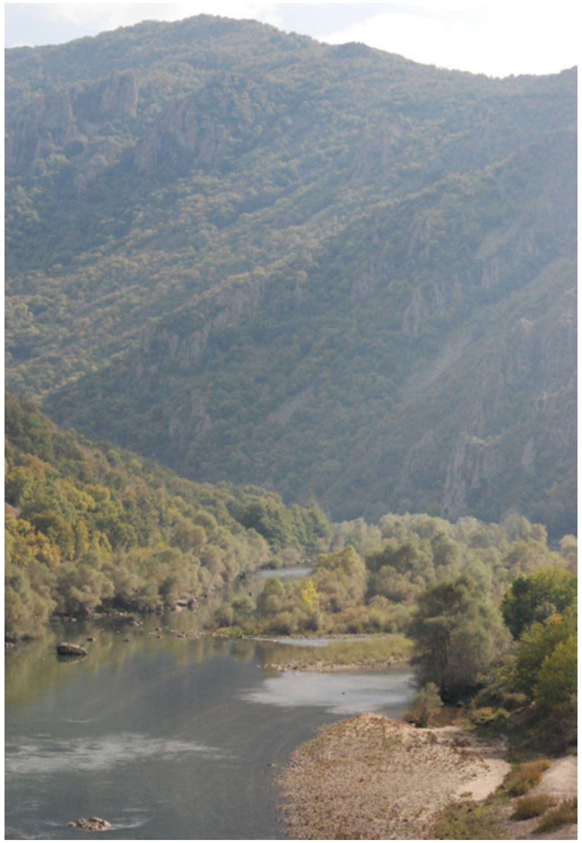


Figure II.10, left
Alpine River, Most Arda, Natura 2000 site BG0002071 Bulgaria. © Theo van der Sluis

Figure II.11, right
Distribution of Alpine Rivers (note that the 2017 report did not include Croatia at the time, so its habitats are not included in the figure).
(*Halada, Aronsson, & Evans, 2017*)

Proposed measures for GI
A larger project looking at the river basin as a whole, is the DRAVA LIFE – Integrated River Management (LIFE14 NAT/HR/000115), a Croatian project with involvement of WWF-Austria. The project foresees three transnational conservation actions, which involve stimulation of more natural river dynamics, decrease of human impact, increase of inter-sectoral river management and cross-border cooperation along the Drava river.

Assessment of Ecosystem Services
Ecosystem services related to the proposed measures, as described above, are discussed in chapter Ecosystem Services and presented in Table III.3. The Alpine river habitat is restored through reversal of engineering works, removal of dams etc. This has limited potential for provisioning services, much more for regulating services like erosion protection, flood protection and maintenance of nursery populations and habitats (in particular fish species). Some cultural services are related to outdoor recreation, as well as inspiration.

c. Temporary Mediterranean ponds (3170*)

Ecology and distribution
Mediterranean temporary ponds are seasonal wetland habitats, subjected to extreme and unstable ecological conditions. Temporary Mediterranean shallow ponds are very shallow (a few centimetres deep) and exist only in winter or late spring. Mediterranean Temporary Ponds provide the microhabitats for crustaceans, macro-invertebrates, amphibians and reptiles. The flora is mainly composed of Mediterranean therophytic and geophytic species of the alliances *Isoetion*, *Nanocyperion flavescentis*, *Preslion cervinae*, *Agrostion salmanticae*, *Heleochloion* and *Lythrion tribracteati* (*Janssen et al., 2016*).

Mediterranean temporary water bodies occur in very small stands. Temporary ponds appear in depressions during the first rain events in the hydrological year. Rainwater accumulates due to the less permeable soil layer underneath the pond, which retains the rainwater. The first flooding ends up infiltrating and/or evaporating. These ponds are hydraulically connected to the groundwater and from the moment the water reaches and surpasses the base elevation of the pond the water retention period becomes longer. Therefore, the hydroperiod of most of these ponds is higher than the one corresponding to simple accumulation of rainwater in soil depressions with low permeability.

The salinity and hydroperiod are probably the most important community structuring factors, in particular for the active and dormant crustacean communities. **The aridification as a result of climate change may lead to a loss of species that come late in the succession, while salinisation may lead to the loss of already fragile freshwater species**. Although resting egg banks can temporarily buffer against unfavorable conditions, persisting bad conditions may lead to their extinction.

Conservation status
The overall conservation status of this habitat type in the Alpine biogeographical region is unfavourable-bad (and deteriorating). There has been no change in conservation status since 2001–2006.

Problem
The habitat has become rare due to river engineering. All countries reported a broad range of pressures, the most important being sand and gravel extraction, canalisation, water deviation, modification of hydrographic functioning, and modification of structures on inland water courses (e.g. small hydropower projects and weirs). Other important pressures are vegetation succession, waste disposal, water pollution, invasive non-native species, removal of sediments, flooding modifications, lack of flooding, surface water abstraction, and construction of dykes and embankments.

Proposed measures for GI

The most important conservation measure reported in the Art. 17 reporting is the establishment of protected areas/sites and legal protection of habitats and species. Additional measures might be to set out management rules for maintaining a favourable conservation status of temporary ponds; also the demonstration of ecological restoration techniques and measures could inspire countries and managers to take action. Another measure is creating a seeds bank specifically for this habitat, which can be used in restoration actions and for the safekeeping of genetic reference for the flora of the habitat.

We must consider these habitats as 'communicating' networks, whereby regular exchange takes place. The habitats are particularly vulnerable because they are small, dynamic and ephemeral. It is therefore important to maintain or improve the connectivity between these habitats. This requires the protection of existing ponds against destruction, restoration of destroyed or overgrown habitats and the creation of new habitats in particular where this would support the network of ponds.

The Project LIFE+ 'Conservation of Temporary Ponds on the Southwest Coast of Portugal' (LIFE12NAT/PT/997), LIFE CHARCOS, coordinated by the 'Nature Protection League (LPN), promotes the conservation of the Mediterranean Temporary Ponds. Among the practical activities that were carried out, the following might be relevant for replication elsewhere:

» Construction of temporary ponds, planting shrubs on the margins of ponds and creating shelters from stone and wood to promote habitat connectivity for amphibians, mammals, reptiles and other biological groups in the pond complex.

» Eradication of exotic plants, shrub control.

» Rehabilitation of ponds with replacement of the natural relief with slight sinking and replacement of the upper organic horizon to ensure the safeguard of the seeds and cysts of the species of the temporary ponds.

» Re-introduction of species.

» Removal of drainage ditches.

The Life PRIMed (LIFE17 NAT/GR/000511) promotes restoration of temporary ponds in the Greek Nestos Delta. Restoring the habitat includes the clearing of the vegetation that covers and falls into the temporary ponds. The shrub removal is necessary for the survival of the species *Emys orbicularis*, *Testudo hermanni* and *Callimorpha quadripunctaria*, present in these habitats. Enlargement of the habitat 3170* area is necessary due to the reduction of the total pond surface area that has occurred during the last 20 years.

Conservation status

Temporary Mediterranean ponds are assessed as unfavourable-inadequate in three regions, as stable in the Mediterranean and Macaronesia and improving in the Atlantic together with unfavourable-bad (deteriorating) in the Continental region and unknown in the Alpine region (Apennines).

Problem

Most important pressures and threats mentioned in the article 17 reporting are changes in hydrology and pollution. Over the last two decades, also changed land use such as modern industrialised agriculture and tourism have caused a steep decline in the condition of this habitat type. Temporary ponds are subjected to strong anthropogenic pressures, such as deep soil turning, accelerated drainage, change of the surface topography or transformation of ponds into permanent reservoirs for irrigation.

Not featuring much in the Art 17 reporting (yet) but increasingly important in the near future will be climate change. Increased temperatures combined with more irregular precipitation will probably result in a shorter hydroperiod, loss of species and fragmentation of habitat and dependent communities. Urgent action is needed in order to assure their long-term protection.

New pond sites should be identified based on the proximity to other ponds and accessibility for plants and animals, as well as on the hydrographic system of the area. A GIS-topographic analysis may help to identify suitable areas where the flow of the rainfall converges optimally, allowing natural filling of the ponds during the wet season. A soil survey may assist to identify areas featuring a waterproof clay substrate, which is indispensable for the persistence of ponds. Based on this site identification approach, a maximum 50cm excavation is required to excavate the temporary ponds.

An additional habitat restoration measure may be the planting of shrubs on the margins of ponds. Also, **the creation of shelters from stone and wood can be important to create additional habitat and improve connectivity for amphibians, mammals, reptiles and other biological groups** in the pond complex. If ponds are too isolated, keystone or target species might be introduced in the pond for those species which are not mobile. Specifically in new sites it might be worthwhile to 'transplant' water with e.g. crustaceans to ensure a fast establishment of temporary pond communities, improve water stability, and spread the risks of loss of species over a larger number of ponds.

Assessment of ecosystem services

Ecosystem services related to the proposed measures, as described above, are discussed in paragraph II.3.3 Example studies for improving network coherence. Conservation, restoration or creation of Mediterranean temporary ponds will have positive effects with relation to erosion protection and climate regulation. In particular the microclimate around ponds will be positively affected, providing some shade and water in an otherwise dry and harsh habitat. The ponds may to some extent positively affect flood protection due to buffering peak rainstorm events. Of particular importance are the maintenance of nursery populations and habitats, as indicated for amphibians, reptiles, crustaceans etc.

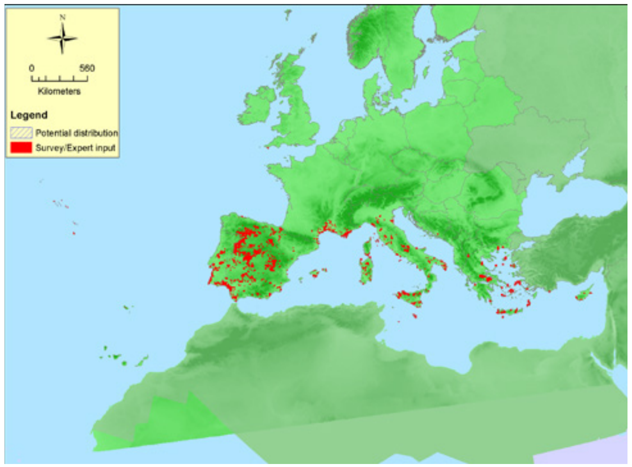


Figure II.12, left
Mediterranean temporary pond, on Kornat island, site HR4000001 Croatia. © Theo van der Sluis

Figure II.13, right
Distribution of Mediterranean temporary ponds, Red List of Habitats
(*Jansen et al., 2016*)

Example species and network cohesion

a. Eurasian lynx (*Lynx lynx*)

Ecology and distribution
The Eurasian lynx (*Lynx lynx*) used to occur throughout Europe, but currently the European distribution is associated with a rather scattered pattern of large continuous forest regions. Important core areas are: East Poland, the Carpathians, the Alps and the Jura Mountains. The species occurs in many biogeographical regions: Boreal, Alpine, Continental, Pannonian, and a small part of the Mediterranean region.

The Czech Sumava and German Bavarian Forest hold recently-established populations. In some Western European regions the species has been reintroduced very recently. The home-range size within these regions varies according to the season, prey density, sex and age. Dense populations are mainly found where prey availability of roe deer and chamois is high. Human activity and intensive land use is tolerated as long as there is enough vegetation cover.

Proposed measures for GI
To strengthen the European lynx population it is essential to improve the connectivity of the landscape, the peripheral areas where small populations face the threat of extinction. Recent lynx observations in Northern Belgium, the southern parts of the Netherlands and the Dutch Veluwe indicate the potential for colonisation of small isolated areas. Spontaneous recolonisation of potential habitat (forest) may be facilitated by incorporating corridors with stepping stones into the ecological network for the lynx.

With the LARCH model* the potential habitat and the connectivity of the landscape were evaluated for the Eurasian lynx. The analysis confirmed that the potential habitat has a patchy distribution. The most effective corridors comprise the area between North-eastern and North-western Poland, the area of Western Poland, the corridor south of Berlin, towards the Harz area and the area between South-eastern Belgium and the French-Swiss Vosges and Jura area.

Transboundary migration occurs in almost all countries in Central and Eastern Europe (e.g. Hungary, Bulgaria, Romania, Czech Republic, Greece, Baltic states). There are specific proposed measures, as described above, that aim at improving the landscape connectivity:

» Life Lynx, a consortium of mostly Slovenian partners, with Croatia and Italy

» the INTERREG project 3Lynx

» LIFE Luchs Pfälzerwald - Reintroduction of lynxes (Lynx lynx carpathicus) in the Palatinate Forest Biosphere Reserve (LIFE13 NAT/DE/000755)

Conservation status
The Eurasian lynx is protected under the Bern Convention (appendix III), EU Habitats Directive (appendix II and IV, for some Eastern European countries annex V), CITES (Appendix II) and IUCN Red list (Least Concern status). The species seems stable throughout most of its territory (*Adamec et al., 2012*). The last article 17 reporting indicated that the species has a favourable conservation status in the Alpine and Boreal region, an unfavourable-inadequate status in the Continental region whilst it has an unfavourable bad conservation status in the Mediterranean, Pannonian and Black Sea region.

Problem
The habitat of the lynx mostly has a patchy distribution; suitable habitat is often destroyed by deforestation and agriculture. As a result, most smaller populations have limited genetic variation or are even inbred. Other problems are related to persecution, low acceptance due to conflict with hunters and shepherds, and vehicle collision.

The landscape is fragmented for the lynx: potential suitable habitat is badly connected with core areas, and peripheral areas are especially badly connected with already occupied areas. The latter is problematic for the species, because relatively small populations of the Eurasian lynx may easily become extinct as a result of environmental stochasticity (random fluctuations), such as prey availability, poaching (nowadays), hunting (in the past) or road kills.

* LARCH (Landscape Analysis and Rules for Configuration of Habitat) is a landscape ecological model to assess species' habitat and viability of populations.

LIFE Lynx project's primary objective is rescuing the Dinaric-SE Alpine lynx population from extinction and to preserve it in the long term. The Dinaric-SE Alpine lynx population went extinct at the beginning of 20th century due to hunting and persecution, habitat loss and lack of prey species. It was successfully reintroduced in 1973 by translocating animals from the Carpathians and Slovenia. The animals spread, but after a few decades the population started declining, mainly due to genetic deterioration.

Currently, the population is small, isolated, and extremely inbred. It urgently needs reinforcement by introducing additional, healthy animals from another population. The Dinaric-SE Alpine population is now reinforced with lynx from populations in the Carpathians. This work is done in close cooperation with stakeholders to ensure broad public acceptance of lynx conservation. Scientific information is incorporated into management plans and other strategic documents. **Improved population connectivity for lynx will improve natural gene flow** within this population. Such a metapopulation will help reduce negative impacts of habitat fragmentation and will reverse genetic deterioration across the entire Dinaric-SE Alpine population.

The INTERREG 3Lynx project has set itself quite a different aim: to integrate lynx monitoring, conservation and management into a common strategy on a transnational level. The project does so **by improving lynx conservation capacities of responsible stakeholders through experience, data and tool sharing** and by implementing a harmonised lynx monitoring at the population level. The project is also an instrument to achieve active involvement of key stakeholders (hunters and foresters) into lynx conservation issues. These are only a small sample of projects, many more initiatives have been listed in *Estreguil et al. (2018)*.

Figure II.14, left
Release of the Lynx 'Bell'. © Martin Greve, Stiftung Natur und Umwelt Rheinland-Pfalz

Figure II.15, right
Eurasian lynx (Lynx lynx) distribution in Europe 2006–2011. Dark cells: permanent occurrence, Grey cells: sporadic occurrence. Red borders mark countries for which information was available.
(*Kaczensky et al., 2013*)

The LIFE Pfälzerwald program's main aim is to re-establish a lynx population in the Palatinate Forest, the transboundary biosphere reserve Pfälzerwald/Vosges du Nord. This is achieved through a reintroduction programme involving the release of 20 lynx (10 coming from Switzerland and 10 from Slovakia). This should result in a reproducing population of lynx in Rheinland Pfalz. The project is also monitoring lynx; it aims to increase public acceptance, cooperation with stakeholders (it is all on public land) and improved spatial connectivity.

Assessment of ecosystem services

Ecosystem services related to the proposed measures, as described above, are discussed in the chapter Ecosystem Services and presented in the Table III.4. Ecosystem services related to interventions for the Eurasian lynx are mostly related to forest habitats that are promoted. The European lynx is very much dependent on extensive and continuous forest habitats. This demands the conversion from cropland to forest, which may reduce some of the provisioning services such as crop and livestock. The development of Green Infrastructure for the lynx will however also benefit a range of mammals through habitat provision, such as red deer, roe deer, wolf, brown bear, badger, wild cat and pine marten. The increased cultural services include outdoor recreation services as well as inspirational services.

b. Stag beetle (*Lucanus cervus*)

Ecology and distribution

The stag beetle (*Lucanus cervus*) is one of the largest insect species in Europe. The larval development in dead wood takes five to eight years. Although females are able to fly and need to do so in order to search for stumps for mating and laying eggs, they tend to stay in the neighbourhood of the stump they emerged from. Chances for colonisation of new habitats are therefore limited. A wide range of woods are used, especially oak, but also ash, elm, sycamore, lime, hornbeam, apple, cherry and even some garden tree varieties.

Figure II.16
Stag beetle, *Lucanus cervus*. © Chris van Swaay, De Vlinderstichting/Dutch Butterfly Conservation

The stag beetle is common only in Northern and Central Spain and Northern Italy and is rather stable. In France the short-term trend is stable, although the long-term trend is unknown. In South-eastern England its populations are surviving well in several core areas. **Distribution patterns of the stag beetle have been shrinking since 1900 in the remaining countries, leaving only small isolated populations**. The stag beetle is one of several rare and threatened saproxylic (woodboring) beetles in Europe, like *Rosalia alpina*, or *Monochamus scutellatus* (white-spotted sawyer).

Proposed measures for GI

To create more breeding possibilities for the stag beetle, old and moribund deciduous trees as well as large stumps of these trees are required. At the local level connectivity can be enhanced by the **introduction of natural and artificial breeding facilities**, such as dead wood pyramids, loggeries and large wooden boxes filled with wood chips and sawdust. The location of these breeding habitats should be based on the core areas already present. The corridors connecting the breeding places should be of the 'nodal type' with nodes every 2km.

The European Red List (*Cálix et al., 2018*) recommends that at the landscape level connectivity can be enhanced with the maintenance of ancient woods, conservation of forest remnants, hedgerows and old deciduous trees. The exchange of individuals between isolated patches of old deciduous woodland can be facilitated with plant schemes for deciduous trees in the vicinity of forest remnants, single trees, open areas and coniferous woodland. These corridors should be constructed away from roads, as stag beetles are very vulnerable to traffic.

Little evidence is found of larger, transboundary projects aimed at the stag beetle: the project LIFE for insects – Conservation of selected Natura 2000 insect species in transboundary area (CZ-SK) of Western Carpathian Mts. LIFE16 NAT/CZ/000731 is focused on the regional scale, and partly on meadows for butterflies. The LIFE description notes, however, that the most threatened habitats in Central Europe are open-canopy middle forests home to valuable Habitats Directive-listed species such as the stag beetle (*Lucanus cervus*) or clouded Apollo (*Parnassius Mnemosyne*) butterfly. With the disappearance of traditional coppicing of woodlands and forest grazing (and changes in forestry practices and legislation), the best way to support this habitat is through the restoration of open-canopy forests.

In South Sweden, a LIFE project aims at restoring saproxylic beetle species (LIFE15 NAT/SE/000772). One of the project aims is to Initiate the creation of decaying wood habitats which in the longer term can bridge gaps in space and time for the *Annex I habitats (9070, 6530*, 9160, 9020 and 9190)* and *Annex II species Osmoderma eremita, Cerambyx cerdo, Lucanus cervus and Anthrenochernes stellae* within the Natura 2000 sites.

Conservation status

The stag beetle is listed in appendix III of the Bern Convention and in appendix II of the EU Habitats Directive. In many European countries the European stag beetle also occurs on the national Red Lists, but it does not occur on the IUCN Red List since the species is not endangered on a global scale. The last article 17 reporting indicated that the species has a favourable conservation status in the Black Sea and Pannonian region whilst it has an unfavourable-inadequate status in the other regions where it occurs. In general saproxylic insects are threatened and in decline.

Animal species associated with old-growth forest and dead wood are among those most threatened in European forest ecosystems. Many studies have demonstrated the susceptibility of forest species to intensive forest management practices and forest fragmentation (Bosso et al., 2018). Saproxylic insects comprise a disproportionately large percentage of nationally rare and threatened species (Grove, 2002). An assessment of the Red List status of saproxylic beetles in Europe was made: saproxylic insects stood out as a highly threatened group (Cálix et al., 2018). At the same time it has been demonstrated that Natura 2000 so far may not have been effective in the protection of rare saproxylic beetles (D'Amen et al., 2013).

Problem

The main risks for the stag beetle are its vulnerability – due to its long life cycle which requires large stumps in an undisturbed environment- and the relatively small dispersal range of the females. It appears that the main condition for survival and gradual dispersal forms a rather dense network of undisturbed patches with old large stumps of deciduous trees and sap trees for adult feeding as well. At the landscape ...

Figure II.17

Observations of Stag beetle in Europe.
(*Harvey et al, 2011*)

One of the methods used is 'veteranisation' of trees: a method to create old tree structures in younger trees, carried out using a chainsaw by arborists. The veteranisation methods aim to mimic effects on trees due to naturally occurring disturbances like storm felling, lightning, browsing animals and woodpeckers. It increases the number of available dead-wood-habitats for threatened species, such as hollow trees, trees with partially dead trunks, and sap flows. So far no results have been reported at lifebridgingthegap.se.

Assessment of ecosystem services

Ecosystem services related to the proposed measures, as described above, are discussed in par. III.5 and presented in Table III.4 (chapter Ecosystem Services). The stag beetle is exemplary for the strongly declining group of large woodboring (saproxylic) beetles, such as the black tinder fungus beetle. If ancient woods are maintained, then ancient woodland indicator plants will also benefit. These old forests have limited provisioning services, and may in fact require reduced timber harvesting. The regulation services may be high though, in particular climate regulation, pollinator functions, seed dispersal and maintenance of nursery populations and habitats. Lastly, the habitat may facilitate some recreational services, as well as inspirational services (*Plieninger et al., 2015*).

... level the beetle is affected by the disappearance and fragmentation of old deciduous forests, leading to smaller and more isolated habitat patches. As a result, the distribution of the beetle is scattered (Figure II.17). Dispersal distances are reportedly up to 3 km (Rink & Sinsch, 2007). At the local level, forestry activities also minimize the remaining suitable habitat because they consist of the removal and disturbance of large pieces of dead wood from the forests and the cutting of deciduous trees for forest regeneration purposes. Consequently, only small stumps are left behind which are too small for proper larval development of the beetle. In addition, the use of herbicides and insecticides threatens the beetle.

The decline and fragmentation of habitat of the stag beetle also affects other saproxylic (woodboring) insects; Figure II.18 shows the richness of forests containing habitats of rare woodboring invertebrates (Cálix et al., 2018). Some forests are of respectable size, but others are as small as 40 ha. The highest richness occurs within mountainous parts of the continent. The distribution pattern demonstrates that forests important for saproxylics are either isolated relicts in unforested regions or – although embedded in large woodland regions – isolated from similar forests.

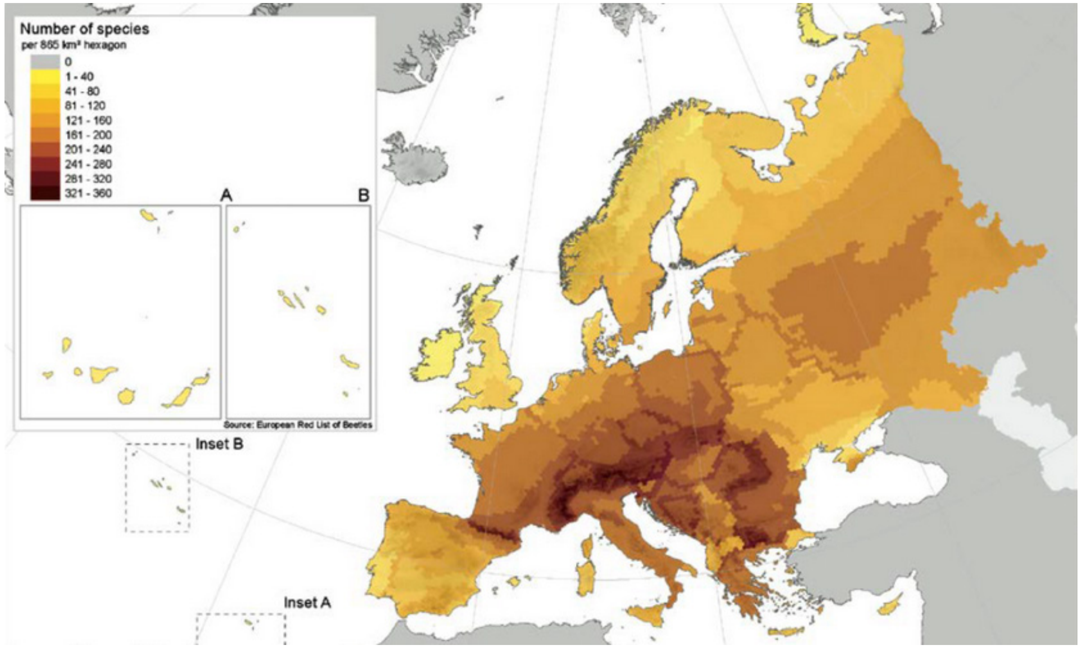


Figure II.18
Species richness of European saproxylic beetles.
(Cálix et al., 2018)

c. European sturgeon/Beluga (*Huso Huso*)

Ecology and distribution

Sturgeons are excellent flagship species for ecologically healthy rivers and seas due to their size, longevity, diverse habitat utilization and their migratory life cycle that connects coastal waters to the upper reaches of riverine ecosystems. **Sturgeon species, together with migratory fish, are useful indicators of the ecological status of a river, especially when considering the river's function as an ecological corridor**. The beluga or European sturgeon (*Huso huso*) is endemic to the Ponto-Caspian Sea region that includes the Caspian Sea (the largest inland body of water in the world) as well as the Sea of Azov and the Black Sea. The current native wild distribution within the EU is restricted to the Black Sea (in the Danube only), but it does occur in the Caspian Sea and Volga as well. As it is a long-lived species (has a long life expectancy), individuals can still be caught in areas where their spawning sites have been cut off. The beluga have reached 100 years of age and more than 1,000kg weight. The last wild population in the Black Sea basin migrates up the Danube river. All other Black Sea stocks are almost extirpated due to overfishing and impoundment of spawning rivers.

Proposed measures for GI

The protection of sturgeon needs a holistic approach, connecting international waters, coastal areas, and often multi-national river systems. A Pan-European action plan was prepared for this species. This plan makes it clear that saving sturgeon from extinction is really a cross-sectoral and trans-national issue: it requires that transboundary networks of people work together to overcome complex problems. In the immediate future, **survival depends on restocking, effective fisheries management, and combating illegal fishing**. Range states are also encouraged to provide protection to the species spawning and feeding grounds. Protective measures include fishing regulation, habitat restoration, juvenile stocking, and the CITES listing of all sturgeon products including caviar. The most important measures are habitat protection, restoration or enforcement of fisheries regulations. These are however in conflict with economic interests, and implementation therefore has proven to be particularly difficult (*Friedrich et al, 2018*).

In the future, sturgeon farming may resolve some pressure on the wild populations (due to illegal fishing), presently farming yields more than 2,000t per year (equivalent to wild sturgeon landings) and about 15t of caviar. This artificial production may contribute to a reduction of fishing pressure and lead to the rehabilitation of wild stocks.

One of the approaches is the MEASURES project developed under the INTERREG Danube Transnational program. MEASURES stands for “Managing and restoring aquatic ecological corridors for migratory fish species in the Danube River Basin”. This project is a partnership with many other institutions from across 10 countries.

Conservation status

The European sturgeon is critically endangered, following the IUCN criteria and included in the EU Habitats Directive Annex V, the Bern Convention Annex II & III. Based on catch data, and number of recorded spawning individuals it is estimated that the species have seen a wild native population decline of over 90% in the past three generations (a minimum of 60 years) and overfishing for meat and caviar may cause global extinction of the remaining natural wild populations. Stocks of sturgeons are dramatically decreasing, particularly in Eurasia; the world sturgeon catch was nearly 28,000 tons in 1982 and less than 2,000 tons by 1999 (Billard & Lecointre, 2000). The last article 17 reporting indicated that the species has an unfavourable bad conservation status in the regions where it occurs.

Problem

The decline of Sturgeon resulted from overfishing and environmental degradation such as: accumulation of pollutants in sediments, damming of rivers, and restricting water flows, which become unfavourable to migration and reproduction.

MEASURES aims to create ecological corridors by identifying key habitats and initiating protection measures along the Danube and its main tributaries. The sturgeons and other migratory fish species act as flagship species in support of these goals. It will achieve this by identifying key habitats and initiating protection measures along the Danube. A combination of measures is required to restore **the landscape connectivity for the European sturgeon. These measures comprise the bypassing of obstructions such as dams, weirs and culverts, the restoration of spawning areas by restoration of the morphology of rivers and streams, and in some cases young fish have been reintroduced in tributaries of big rivers**.

In 2019, project partners in Hungary began work to build a sturgeon hatchery whilst also undertaking two pilot restocking actions. Thus, 5,000 sterlets fitted with yellow identifier tags have been released into the Danube. From April 2020, the released population's growth rates and travel routes will be assessed.

The corridor required for migration and dispersal is of the 'linear type'. A coordinated approach is required though; the connectivity may be a major problem, a chain of measures is required for sturgeon to reach its spawning areas.

Assessment of Ecosystem Services

Ecosystem services related to the proposed measures, as described above, are discussed in par. III.5 and presented in Table III.4 (chapter Ecosystem Services). The sturgeon populations can be restored through reversal of engineering works, removal of dams etc. This has some potential for provisioning services, in particular for fisheries. More important are the regulating services like erosion protection, flood protection and maintenance of nursery populations and habitats. The habitat finally may facilitate some recreational services (fishing), as well as large inspirational services.

Figure II.19, left
Sterlet Acipenser ruthenus. © Hans Braxmeier (Pixabay.com)

Figure II.20, right
Fish hatchery for Danube sturgeons. (www.interreg-danube.eu/approved-projects/measures/gallery)

d. Large copper (Lycaena dispar)

Ecology and distribution
The Large copper (*Lycaena dispar)* usually occurs in natural marsh vegetation along water courses, rivers and marshes, but may also be found in unimproved, semi-natural grasslands. The male defends his territory, whilst the female wanders over large wetlands looking for a male or – after mating – for a plant to deposit eggs. The females are quite mobile and ccan colonise suitable habitats relatively quickly up to a distance of ten km. This means that the butterfly functions very well in mosaics of habitat patches. The large copper has declined significantly in Western Europe, whereas Eastern European populations are mostly stable. At the northern limit of its range in Estonia and more recently in Finland, the butterfly is expanding, probably caused by global warming in the last decades.

Figure II.21
Large copper *Lycaena dispar*. © Chris van Swaay, De Vlinderstichting/Dutch Butterfly Conservation

Proposed measures for GI
To increase the connectivity for the Large copper two types of corridors are required. Firstly corridors connecting different networks and secondly corridors which link smaller local populations within a particular network. The landscape matrix is very important for the development of such network corridors, but also linear corridors with attached nodes are needed to link the smaller local populations. This is illustrated in Figure I.22.

In the North-western part of Germany wetlands are small and isolated. This means that the Large copper population occurring in the Netherlands is isolated from populations in Eastern Germany. Only a large scale creation of wetlands could be a solution to this problem.

It is important that existing wetlands with *Lycaena dispar* populations are maintained and the area is connected to the east with the Biebrza valley and Kaliningrad.

The Large copper is an umbrella species for many other wetland insects. But also other species of large wetlands, such as the Otter and many birds will profit from action taken to favour this butterfly.

Assessment of ecosystem services
The habitat for the large copper is much related to large wetlands and meadow systems, which should be restored. This has limited potential for provisioning services, some wild animals, but much more important are plant-based resources, reed used for roofing, for biomass, pellets etc. (*Van der Sluis et al., 2013*). These wetlands also provide important regulating services, in particular climate regulation, flood protection and maintenance of nursery populations and habitats (in particular fish species). The areas also form important recreation areas for hikers, canoers, fisherman or hunters. Also, inspirational services are associated with large wetland areas (Table III.2).

Conservation status
The Large copper is listed on appendix II and revised Annex I (requiring specific conservation measures) of the Bern Convention. It is on appendix II and IV of the EU Habitats Directive. The butterfly is listed as 'Least Concern' on the European Red List (*Van Swaay et al., 2010*). The last article 17 reporting indicated that the species has an 'unfavourable-inadequate' status in most biogeographical regions (Atlantic, Boreal, Pannonic, Steppic region) and favourable conservation status in the Alpine, Black Sea and Continental region. At the national level it is reported as 'unfavourable-bad' in The Netherlands and Germany.

Problem
The biggest threat to the Large copper is a decline in habitat quality, in intensively farmed regions by lowering of the groundwater level and nitrogen deposition. In abandoned areas the threat is by succession turning open habitats into secondary forest. Smaller and degraded habitat patches suffer under fragmentation of their habitat.

By means of a LARCH analysis potential habitat of the Large copper was identified and compared with the actual distribution pattern of the species (Fig. I.22). In many areas (1, 2, 3) large core populations exist whereas in other regions populations are smaller, but still well connected (4, 5). In areas such as North-western Germany (6) however the wetlands are too small, scattered and isolated. Although the ecology differs slightly for this species, the model also predicts reasonably well the potential distribution of the Large copper in the Netherlands. In reality this subspecies is restricted to the Dutch regions of Northwest Overijssel and Southern Friesland.

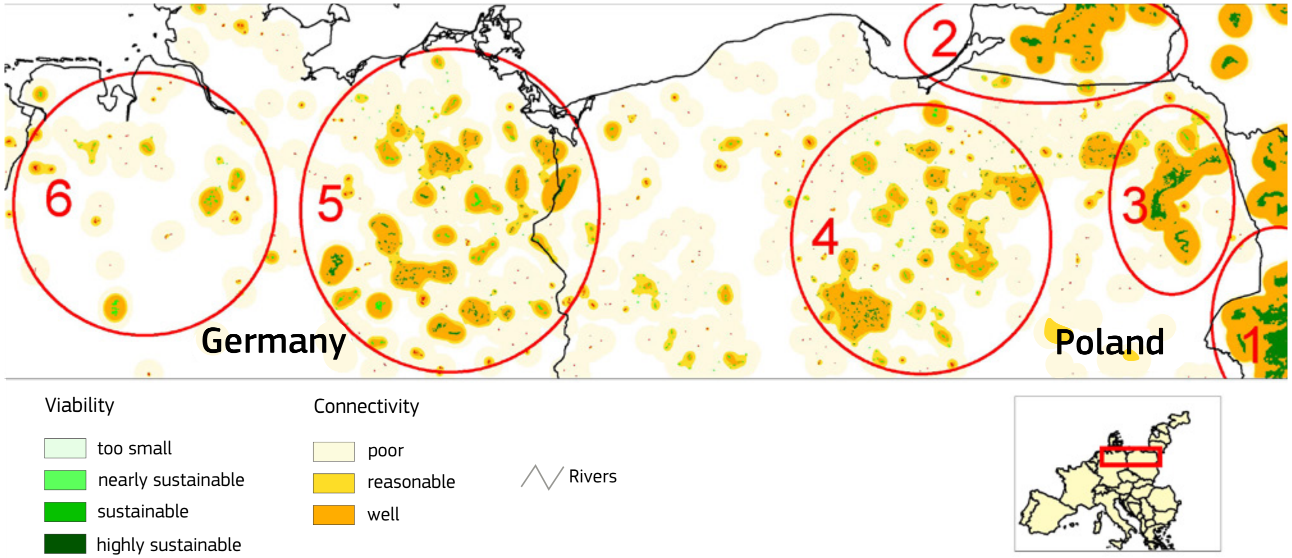


Figure II.22
Ecological core areas for the Large Copper.
(*Van der Sluis et al., 2004*)

II.4 Key findings and recommendations

II.4.1 Key findings

We may conclude that the **various concepts used (ecological networks, corridors, green infrastructure, network coherence) vary**, which can be explained by changes in priorities and policy targets over time. In the end, most boil down to the same concepts, whether it is called Green Infrastructure or ecological network.

The policies and approaches vary a lot in the different Member States. Also here policy plays an important role, as well as cultural differences and approaches adopted in planning: strong central planning, or decentralized approaches, bottom-up or top-down.

Important is the involvement of stakeholders in planning for improved network coherence, stakeholders can contribute, can add to planning processes. This is very much in line with the various directives and implementation guidelines, as well experiences gained in various projects.

II.4.2 Guidance, recommendations; practical information for practitioners

What is happening in the EU-countries?

The situation with regard to biodiversity and Green Infrastructure is available on BISE, Biodiversity Information System for Europe. This site has a link to every country, biodiversity fact sheets, but also information on MAES reporting and Green Infrastructure per country. This report provides a brief overview of the history and initiatives in Europe. A review of initiatives wordwide is presented by *Keeley et al., 2019*.

What tools exist for improvement of Network Coherence?

Network coherence or Green Infrastructure can be improved through a variety of measures. The landscape cohesion is very much defined by species characteristics: range, habitat choice, dispersal distance, carrying capacity. These are species specific characteristics which cannot be changed. The landscape itself can to some extent be adjusted.

There are various reports that provide guidance on ecological network development and the relevance of corridors, such as the handbook from IUCN (*Hilty et al., 2020*). Also the guidance for Green Infrastructure, prepared by JRC is very relevant (*Estreguil et al., 2019*).

In this report also practical GIS-based tools and knowledge systems are presented. One is the LARCH model. This model was used in several examples in this chapter, e.g. for the Large copper, but also various regional studies (in Italy, Catalunya, Poland).

It is recommended that a working group be established to adequately help the implementation of Article 10 to support achieving Favourable Conservation status.

Targeted materials should be developed for different stakeholders (government authorities at national, regional and local levels, NGOs, the public etc.) to clearly demonstrate and explain the network coherence in terms of reaching Favourable Conservation Status, thus showing the functional aspects of the raised attention for Article 10.

Which projects might be relevant?

The MaGICLandscapes Interreg project (2017–2020) focuses on Green Infrastructure implementation. The website introduces the Green Infrastructure concept and its benefits. In close cooperation with local stakeholders, project partners elaborate strategies and action plans to enhance the existing Green Infrastructure in Central Europe. The project promotes sustainable land use by providing land managers, policy makers and communities with tools and knowledge.

The website also provides a link to the output of the project, with the 'Green Infrastructure Handbook – Conceptual & Theoretical Background, Terms and Definitions' (*John et al., 2019*). The Handbook provides a table with the countries of Central Europe, and what they are doing on GI. In addition, fact sheets are provided on GI, currently in 5 different languages.

Basically, the options for improvement of landscape coherence or connectivity are:

- Through development or improvement of corridors
- Improvement may entail widening, adapting the vegetation to provide more cover for species, establishing water points or stepping stones etc.
- Enlargement of core areas, conservation areas, by enlargement and improvement of habitat
- Improvement of the 'matrix', the surrounding landscape, e.g. through stimulation of low-intensity farming, reduced use of agro-chemicals, or more natural forest managements for forest corridors, better conservation of the riverine vegetation and avoiding expansion of human settlement.

Financial instruments

As demonstrated in par. II.3.2, the LIFE program is and has been of major importance to develop, restore or improve Green Infrastructure and network coherence.

Financing of measures for Green Infrastructure is possible through the Natural Capital Financing facility. This facility is in particular meant to halt the loss of biodiversity and adapting to climate change. To do so, the European Investment Bank (EIB) and the European Commission have partnered to create the Natural Capital Financing Facility (NCFF), a financial instrument that supports projects delivering on biodiversity and climate adaptation through tailored loans and investments, backed by an EU guarantee.

The NCFF also provides a ‘seven-step guidance’ on financing, a 40-page document describing the ways of financing conservation and nature-based solutions measures. Except for financing measures related to Green Infrastructure, they also provide loans for pro-biodiversity and adaptation of businesses (e.g. forestry, farming, ecotourism, energy), payment for ecosystem services. Also, several examples of funded projects are provided.

Recommendations should be developed on the use of other legal and policy instruments, that could or do support ecological coherence, financial instruments, planning instruments and specific programmes (e.g. Water Framework Directive, Agricultural Policy (CAP), Fisheries Policy (CFP), Cohesion Policy and Structural Funds, spatial planning, wildlife conservation programmes).

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Annex I: Country descriptions

Austria

The **Federal Republic of Austria** consists of 9 independent states (*Länder*). The competence of the Länder includes all areas that are not explicitly attributed to the federation by the Federal Constitution (*Bundesverfassungsgesetz*). Within this federal system, nature conservation, hunting and fishing are domains of the Länder, whereas agriculture, water and forestry are domains of the federation. There is no federal law establishing a framework for detailed nature conservation legislation by the Länder. The basic protection of species and landscapes is regulated by the nature protection acts (*Naturschutzgesetze*) of the Länder. Details are determined by ordnances. Parliament Acts (*Gesetze*) are promulgated in the official gazettes of the Länder as well as ordinances (*Verordnungen*). The nature conservation laws of the Länder that are currently in force stipulate a general obligation to protect and care for nature as the basis of life for mankind, fauna and flora. They also have special regulations with regard to the protection of species, areas and licensing certain activities. The states in the federation are also responsible for the international agreements concerning nature and landscape conservation such as the identification of Natura 2000. National environmental information coordination such as the State-of-the-Environment Report is carried out by the Umweltbundesamt. Since 1998 the, Umweltbundesamt is as a Limited Liability Company. It acts as the expert authority of the federal government for environmental protection

Most of the connectivity restoration activities are carried out jointly by the states and NGOs such as the Alpen-Karpaten corridor and stream restoration.

Figure II.23, left
Alpen-Karpatenkorridor

Figure II.24, right
March Auen project

Belgium

Belgium is a federal country and has three regions (Flanders, Brussels and Walloon) and three communities (Dutch, French and German). Nature conservation and biodiversity conservation is regionalised and Brussels, Walloon and Flanders have different approaches. There is a national strategy on biodiversity for the period of 2006–2016, agreed upon in 2006 by the Interministerial Conference of the Environment consisting of the ministers of the Federal Government, of the three regions (Flemish Region, Brussels Capital Region and Walloon Region) and the three communities (Flemish, French and German). This is a National Policy Document on biodiversity, which summarizes the responsibilities of different governments in Belgium with a view to comply with the commitments made by Belgium on the European and international plans. This strategy has been updated in 2014 for the 2020 targets. It outlines a framework for the policy to be followed and implementation measures to be developed.

Through state reforms, the regions in Belgium gained full competence and responsibility for environment and conservation issues. Supporting research is the responsibility of the three communities. On the French website the ecological network is indicated as "all habitats that can provide a temporary or permanent living environment for plant and animal species, in accordance with their vital requirements, and to ensure their long-term survival". For Walloon and Brussels this is not further spatially elaborated.

The Flemish government is leading the process of developing a Flemish Ecological Network. In the Flemish Decree on Nature Conservation (1997) there are articles concerning:

» Adoption and translation of European regulation and categories in appropriate articles. However, there is no explicit relationship with Natura 2000.

» Definition of the Flemish Ecological Network with core areas and nature development areas (VEN).

» Definition of the Integrated Multifunctional and Supporting Network with nature integration areas (a kind of stewardship areas) and nature corridors (IVON).

A target for the VEN is to protect 125.000 ha (9.3% of Flanders). According to the Nature Decree, this must be demarcated by the beginning of 2003. In 2009, the Flemish Parliament added an explanation to the decree stating that this is a target date as the process is slow. The nature integration areas (IVON) are supposed to cover 150.000 ha. The Flemish Decree on Physical Planning aims to incorporate nature conservation targets (VEN, IVON) into physical planning objectives. The provinces have the responsibility to realize ecological corridors. In the stage of realization of individual projects, informal cooperation with private stakeholders has to be established. This is partly done for the nature restructuring projects where landowners, farmers, hunters etc. are involved and persuaded into a 'nature-friendly' management. For the realisation of the corridors cooperation on a voluntary base is the rule. The negotiations between sectors and their legal bodies on the level of the competent administration (nature conservation, agriculture and forestry) are time consuming. Constraints arise at the regional as well as at the local level. Conservation ecology experts deliver information to the officials at the regional level e.g. the Institute of Nature Conservation maintains the databases on habitats and species and prepares the preliminary maps of habitats for the designation process.

In the desired VEN scenario and additional existing green regional plan designations, there would be a significant decrease in the fragmentation until 2011, since that is when the process stopped. Fragmentation remains an important issue in Flanders. Approximately 14 years after the expiry of the date that has been set in the Nature Decree and eight years after the target year in the IVON, 3% (around 5,084 ha) has been demarcated.

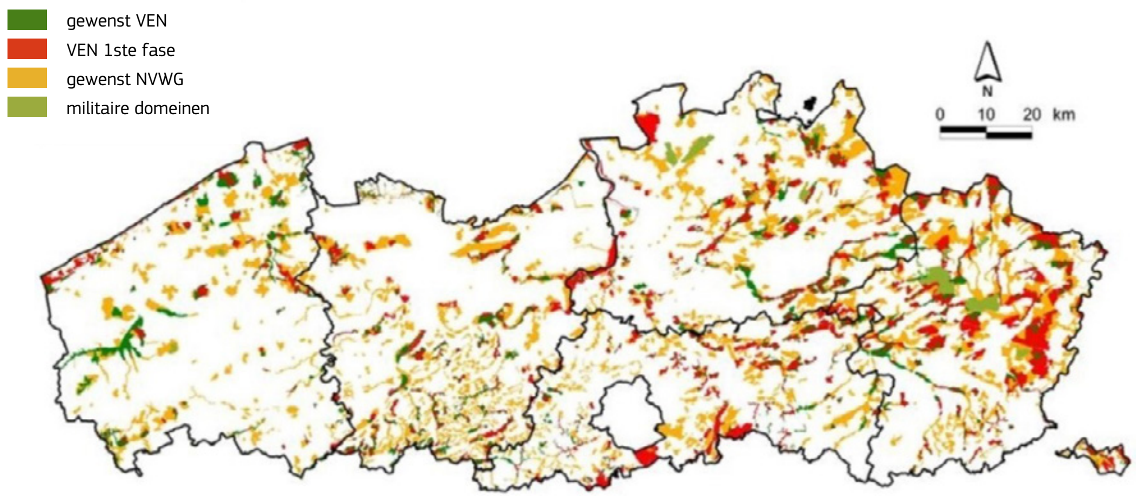


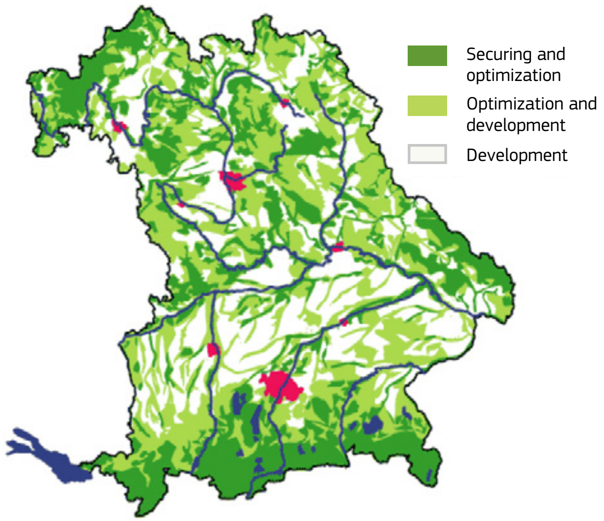
Figure II.25
VEN and IVON in Flanders

Germany

Germany is a federal republic, consisting of 16 member states. The states (*Bundesländer*) are relatively autonomous regions; many have been self-governing kingdoms in the past. In total, Germany identifies six layers of government: the Federal Authority (*Bund*), States (*Länder*), physical planning regions (*Regierungsbezirke*), Counties (*Bezirke*), Districts (*Kreise*), non-district cities (*kreisfreie Städte*) and Municipalities (*Gemeinden*). The Bundesnaturschutzgesetz is a framework legislation: the Bund has the right to enact general laws that are worked out by the Länder (*Rahmengesetzgebungskompetenz*) and the Bundesländer determine the precise institutional forms of enforcement. The present federal nature conservation law, BNG dates from 1976 and its last revision is from 2009. In the revision of 2003 the obligation has been included for the Bundesländer to develop an Ecological Network for the state.

Figure II.25
The Bavarian Ecological Network

Bayern state ecological network, with core areas



One of the major tasks in a federal state like Germany with devolved responsibility for nature conservation is the integration of the state networks into a German ecological network. States and federation work together on this under coordination of the Federal Nature Conservation Agency (BfN) (*Fuchs et al., 2010*). Also, the protection of NATURA 2000 sites is included in this the national nature conservation legislation. In Germany, landscape planning is an important instrument for nature and landscape conservation as well, and enshrined in the 1976 Nature Conservation Law. Landscape planning is, besides a control instrument for nature conservation, a sectoral planning system for all other fields of interest that have to take account of nature conservation interests. Through landscape planning, nature conservation criteria can be taken into account in planning and administrative procedures and the ecological network be realised. The NGO BUND (Friends of the earth Germany) has prepared a handbook for implementation of ecological networks (in German). It relates in general to the physical planning area, but it also contains measures without physical objectives, such as regulations for the protection of animal- and plant species. The second important principle introduced in planning is the Intervention regulation (*Eingriffsregelung*): it is of major importance for species and biotope protection outside the protected areas. It is meant to prevent avoidable impact and to compensate unavoidable measures that damage nature and landscape processes. The objective of the intervention regulation is to preserve the functionality of the natural environment and the landscape also outside the special protected areas. The most common types of intervention are building of housing areas and traffic infrastructure. Interventions in nature and landscape should be avoided according to the nature conservation intervention regulation. If this is not possible, landscaping measures (so-called compensation and mitigation measures) must be taken. With this procedure, a comprehensive approach based on all protected nature areas and the landscape is pursued nationwide. The intervention regulation is of fundamental importance for the achievement of the objectives of nature conservation and landscape management in general.

Defragmentation is an important issue in Germany. Work on defragmentation is organised by the states in cooperation with the federal office for nature conservation, consultants and universities, such as the university of Kiel and the university of Kassel.

In the planning and realisation of linear infrastructures (construction of new roads and expansion of roads, railways, canals) is the existing ecological interconnectedness to be preserved in such a way that colonization and repopulation of habitats by naturally occurring species can take place in sufficient numbers. For this purpose, both the networking relationships and the necessity of measures must be demonstrated and sufficiently justified at various planning levels. An important planning aid for assessing the need for reintegration measures are the habitat networks for dry habitats, wet habitats, near-natural forest habitats and the habitat networks for larger mammalian forest dwellers (*Hänel & Reck, 2011*). Depending on the affected habitats and species, special measures can then be planned to preserve these network relationships. These include a variety of technical options for road crossing such as green bridges and underpasses. There is an important road defragmentation programme, as is formulated in the national strategy on biological diversity (Vision B2.8): In 2020, the existing roads are generally not hindering the connectivity in ecological networks.

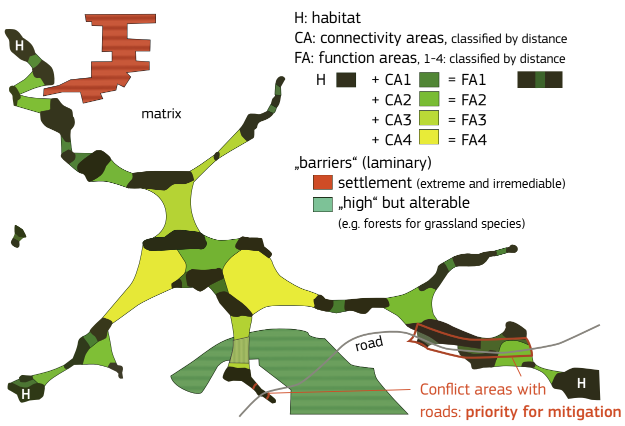


Figure II.26
Identification process of barriers and corridors for mitigation measures

These technical structures are measures with which, if successfully integrated into the landscape, habitat networks can be maintained or restored. With appropriate structural design and e.g. fences the frequency of accidents with larger vertebrates such as red deer are reduced, which contributes to traffic safety. Depending on the affected species, it may be necessary to carry out additional measures in the vicinity of road crossings with which their habitats are improved. The aim is to stabilize remaining populations and to promote their dispersal ability.

Spain

Spain is a federal country; within the period that it is a member of the European Union, regionalization has taken place as well as strong economic developments. Both have an impact on nature conservation. Spain consists of 17 autonomous regions. The regional governments carry the responsibilities for environmental protection and nature conservation. There are a number of national protection categories and Spain has a large territory with protected areas. However, each autonomous region has its own approach to nature protecting, with different priorities towards nature conservation. At present the area covered by Natura 2000 is 134.150 km². There are fifteen National Parks divided over eleven autonomous regions. The National Park is the highest protection category for areas of high natural and cultural value and only scarcely inhabited. In all of Spain the cañadas or routes, originally for merano sheep used to be important for livestock movement from the summer pastures (*puertos*) in the Pyrenean and Cantabrian mountains through even major cities such as Madrid, to the winter grasslands in Extremadura and Andalucía. They have a legal protection status that is differently organised in each region, but they form the largest network of natural areas covering a large part of Spain.

This network of drove roads has been recognised by the national government. In December 2007, the Spanish Parliament adopted a new Nature Conservation Act (Ley 42/2007) which includes ecological networks and ecological corridors. Article 3 defines ecological corridors, connecting natural sites of special importance for wild flora and fauna, allowing genetic exchange between otherwise separated populations. Article 17 defines ecological networks as a network of sites of high natural value which allows the movement of flora and fauna species. It also specifies that nature management plans have to contribute to connectivity conservation and restoring corridors (Art 21). It mentions as important corridors: river courses, drove roads (*cañadas*) and mountain ranges.

At present there are three regions that have developed ecological network plans; Catalunya, the Basque Country and Madrid. In 1992, in Cataluña the plan for spaces of natural interest (PEIN) was created, which was the first coherent plan that delimits and establishes a conservation system for basic protection of representative natural spaces in accordance with their scientific, ecological, landscape and cultural importance. They represent approximately one third of the whole of the Catalan territory and within them it is forbidden to build and hunt. Studies were done on improvement of the ecological network, e.g. with the model LARCH (*Franz et al., 2011*). Later in the Basque country (2005) and Madrid (2010) ecological networks have been designed. For both it is not yet clear how implementation is taking place. In Navarra the first concept of an ecological network has been established in 1997, but then further elaboration has been stopped. In Extremadura the law on Nature Conservation (Ley8/1998) includes ecological and biodiversity corridors. However, the concept has not yet been implemented. One of the important causes of delays seems to be the lack of resources. Another problem is the fact that regional planning is focusing on urban areas and town planning and that land use planning for rural areas is lacking.

NGOs are very important in pushing developments in Spain. For instance in 2013 the Fundación Oso Pardo has been set up that is including the governments of Asturias and Castilla y Leon several municipalities in the Cantabrian Mountains. It is developing with EU-Life+ funds connectivity between the western and eastern populations of the brown bear. There are several associations involved in the use and protection of the Spanish cañadas as well as with single species and species groups, such as the Spanish Ornithological Society (Sociedad Española de Ornitología), that is campaigning to get all areas currently designated as Important Bird Areas (IBA) to be given Special Protection Area (SPA) status.

Figure II.27, left
The Cañadas reales of Spain

Figure II.28, right
Cañada real de Segovia with grazing cattle

Italy

Italy is rich in biodiversity with its long north-south gradient. In the 1970s, part of the competences for area protection has been devolved from the State Government to the 21 regional administrations. Many natural parks came under the jurisdiction of the regions and new ones were created. The result of these experiences was not only a notable growth of protected areas surface but but also the beginning of the discussion that led to the new law n. 394 of 6 December 1991 that proposed protected areas, parks and reserves network to actively protect the ecological system of the country. This law aims to establish a shared distribution of responsibility among the State, the regional administrations and local administrations and to ensure adequate sector planning which enables significant parts of the country to be placed under special protection. This legislation is still valid and in accordance with its general principles the present Regional Act lays down rules for the creation and the management of protected nature areas in order to guarantee and encourage the conservation and improvement of regional natural and environmental resources. The central government is responsible for the implementation of international and national policies.

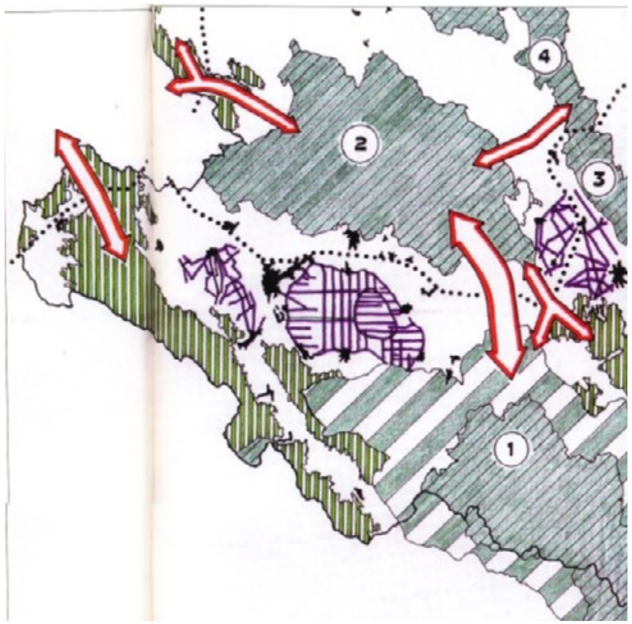


Figure II.29
The connectivity between national and regional parks in the Central Apennines (*Romano, 1996*)

The authorities involved in nature conservation in a strict sense (habitats, ecosystems, species, sustainable planning, etc.) at the national level are the Ministry of Environment; the Ministry of Agriculture, the Ministry of Public Works and the Ministry of Cultural and Environmental Heritage (landscape protection). The Ministry of Environment has frequent relations with Regional bodies in official works for protected areas and the safeguard of species and habitat.

In Italy there are twenty one regions with an increasing autonomy, 103 institutional bodies of second level, which includes 80 provinces, two autonomous provinces, six free municipal consortia, 14 metropolitan cities and 7954 municipalities (2018). The State generally has a coordination role. Each Region has to produce a regional legislation and often Provinces and Municipalities issue local regulations. In management of protected areas state, regions, provinces, and municipalities all have responsibilities in managing parks and reserves at national, regional, provincial and municipal level. This means that regions draft regional scale framework laws and regulations; local authorities such Provinces and Municipalities define rules for application.

This situation regarding task sharing allows much freedom for the different authorities to develop their own vision of nature conservation and the development of ecological networks.

Territorial fragmentation and ecological connectivity have been studied and addressed within regional authorities as well as within research institutes and universities. ISPRA published in 2003 guidelines for the management of functional ecological connection areas, containing practical information on the issues of conservation, planning and management of ecological corridors. Several regional networks were developed, e.g. through the LIFE-Econet projects such as for parts of Emilia Romagna (*Van der Sluis et al., 2001*; *Van Rooij et al., 2003*), Abruzzo (*Van der Grift & Van der Sluis, 2003*; *Van der Sluis et al., 2003*) and Umbria (*Van der Sluis & Pedroli, 2004*). The LARCH model was used to analyse the landscape and territory, and with habitat modelling of target species an ecological network was proposed and partly implemented through regional initiatives and with project funding from LIFE and regional authorities.

In Italy, ecological connectivity has been elaborated at all levels, between national and regional parks, such as in the central Apennines, around towns such as around Milano and in rural areas such as the water network in the province of Bologna.

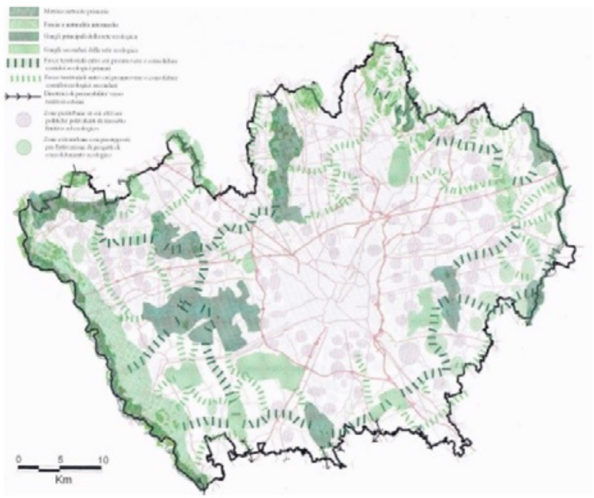


Figure II.30, left
Ecological network of Milano
(*Dimaggio & Ghiringhelli, 1999*)

Figure II.31, right
Aquatic ecological network in the region Bologna (Emilia Romagna). The dark blue areas represent core area, the streams the corridors. The arrows are smaller corridors connecting the streams.
(*Bolck et al., 2004*)

Bulgaria

In **Bulgaria,** nature conservation dates from the beginning of the twentieth century when acts on forests management, hunting and fishing that included some protective measures, were adopted. The first Act, the Nature Protection Act adopted in 1967, had a clearer focus on the international legal norms. It envisaged measures for preservation and sustainable use of the natural resources. In 1992, the Environmental Protection Act, which sets up the contemporary framework of the state policy and management, has been approved. In the same period the Ministry of Environment was established and Bulgaria signed the Bern Convention and the Convention on Biological Diversity. In 1998, the Protected Areas Act was adopted and this is the first specialized nature conservation law. It introduces contemporary, adequate to the international norms, a system of protected areas categories and defines the hierarchy between the institutions responsible for their management. This law has also imposed the elaboration of management plans, determining the concrete regimes for each protected area. The description and management plans for NATURA 2000 are publicly available. In 2002, the relations between the state and municipalities as well as between juridical and real persons have been regulated concerning the protection and the sustainable use of the biological diversity. This Biological Diversity Act regulates the protection of habitats, of species of plants and animals and their biotopes. It introduces the requirements of the Habitats and the Birds Directives, focused on preservation of habitat types and biotopes of plant and animal species. The Act on the Biological Diversity envisages the establishment of National Ecological Network, consisting of three elements – protected zones, protected areas and buffer zones. This National Ecological Network has to include with priority identified SCI sites, Ramsar sites and Important Bird Areas.

Figure II.32
Bottlenecks in the Bulgarian road and railroad network. Blue bullets indicate existing bottlenecks road and railroad network for wild species. Red: main roads, yellow: regional roads. The bigger the bullets the more species are involved.

Bulgaria is currently in a phase of political and socio-economic transition and faces many challenges in balancing economic and environmental interests. One of these challenges is the development of a sustainable road and railroad network that facilitates the needs for efficient transport of goods and people but does not threaten areas that are especially valuable for nature conservation. At present this is a field where important conflicts occur and decisions have to be taken such as the motorway to Greece that is planned through the Kresna Gorge. The rapidly growing road network in Bulgaria, initiated by EU strategies to construct Pan-European Transport Corridors, results in increasing conflicts with biodiversity objectives and the aim of establishing a NATURA 2000 network. Therefore, one of the big challenges at present is the mitigation of fragmentation of the landscape by roads and railways. The implementation of a plan for road and railroad mitigation will significantly improve the population viability of most threatened wildlife species. This is an indispensable first step in preserving Bulgaria's biodiversity and developing a coherent and sustainable ecological network across the country. A first inventory has already been made in 2008, but the process is slow.

Slovakia

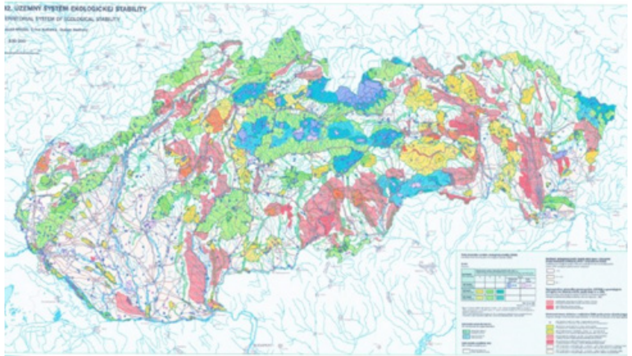


Figure II.33
TSES Slovakia (*Landscape Atlas of the Slovak Republic, map 92, Ministry of the Environment, 2002*)

The concept of ecological networks was formulated in the 1970s as the Territorial System of Ecological Stability (TSES) and it has been applied in the planning practice in former Czechoslovakia and still now in **Slovakia** as well as in the Czech Republic. The main purpose of the establishment of ecological networks in the Slovak approach is the preserving of spatial ecological stability of the landscape. The concept of TSES was a pioneering ecological network at national, regional and local levels. It was one of the first comprehensive concepts of this kind (*Miklós et al., 2019*). It represents a hierarchical connectivity concept of ecological core areas (biocentres) of different importance connected by biocorridors. Biocentres maintain the food chain as well as the conditions for reproduction, protection, resting place and shelter. The main principle was that a set of valuable nature reserves does not automatically constitute an ecological network: it becomes one only after interconnectivity of the reserves has been established.

TSES is incorporated into the legislation for territorial planning and nature conservation (*Buček & Lacina, 1984*). TSES developed in Slovakia as a part of the so-called General Ecological Model of the Slovak Socialist Republic and later incorporated into first official environmental policy issued by the Slovak Commission for the Environment (*Miklós, 1991*). TSES projects in Slovakia were carried out top-down, from the General Plan of supra-regional TSES, through regional to local TSES. Following the General Plan, the National Ecological Network (NECONET) was set up based on the concept of the European Ecological Network and building on principles of the Dutch National Ecological Network. The regional TSES (RTSES) have been developed in the years 1993–1995 for all 38 regions at a scale of 1:50,000. Local TSES projects were in general made as a part of spatial planning procedures.

Figure II.34, left
Floodplain restoration as compensation for the Gabčíkovo–Nagymaros Dams.

Figure II.35, right
Special Protection Areas in Slovakia

When Slovakia joined the EU, the European system of NATURA 2000 was integrated in the TSES projects. The establishment of biocentres and biocorridors is the best-developed part of the TSES system. Also "ecostabilising measures" are a part of the TSES especially in agricultural areas. In the first decade these aspects were less elaborated and used; nevertheless, the concept of the TSES is considered as one of the most notable and evident successes of incorporating landscape-ecological principles into the legislation and spatial planning. In 1990, spatial planning came under the Ministry of Environment. As a consequence, the law "turned greener" through amendments which define that:

» A landscape-ecological plan is an obligatory regulation for utilisation and spatial arrangement of territory.

» TSES or its elements (biocentres, biocorridors, interactive elements, and 'ecostabilising' measures) are defined as an obligatory designation.

» The purpose of the act is, inter alia, preserving the diversity of conditions and life forms on earth, as well as achieving and maintaining ecological stability of TSES and its whole-territory structure.

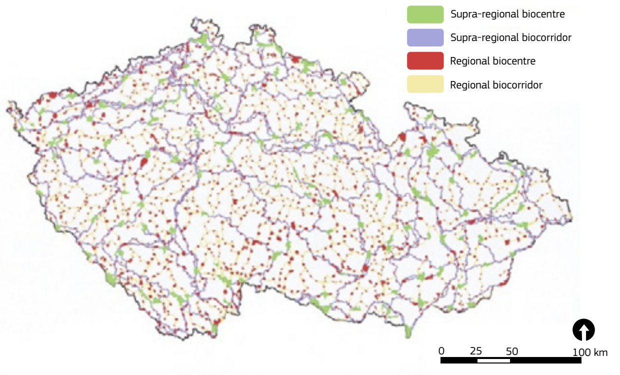
» Establishing and maintaining of TSES is a public interest.

» New "networks" are integrated: the national network of protected areas and the European protected areas network NATURA 2000.

Czech Republic

In the **Czech Republic** nature conservation has a long tradition as the first forest reserve (the Hojná Voda Virgin Forest) was created in southern Bohemia in 1838. The concept of ecological networks and its application in the planning practice in former Czechoslovakia and later in Slovakia as well as in the Czech Republic was formulated as the territorial system of ecological stability TSES. The Czech National Council Act No. 114/1992 (Gazette on Protection of Nature and the Landscape, 1992) is based on an integrated approach. Its main idea is that not only specially protected parts of nature should be conserved for the future but that it is also important to maintain natural processes in ecosystems and landscapes, stressing diversity and importance of life-supporting processes in various biological systems. The purpose of the law is to contribute towards the preservation and restoration of the natural equilibrium in the landscape. The present legislation based on a holistic or integrated approach has also tried to deal with unprotected agricultural and forest lands, using a national concept of TSES (Territorial System of Ecological Stability) at various levels. The concept of TSES started in the 1970s as a pioneering ecological network at national, regional and local levels in Europe. The Ministry of Agriculture is responsible for forest management (except in the three national parks) which is expressed in the Forest Act (Act. No. 289/1995 Gazette). Therefore, the program defines more than 40 priorities in medium- and long-term scale for nature conservation and landscape protection in the Czech Republic and is explicitly based on cross-sectoral approach, incorporating nature management issues in various sectors (agriculture, forestry, regional development, physical planning, transport, tourism, education, etc.). In 1994, the Ministry of the Environment of the Czech Republic implemented the National Biodiversity Conservation Strategy in the Czech Republic dealing with biological diversity at all three levels (genes, populations/species, and habitats/ecosystems) as a basis for its holistic approach.

Additionally, in the Czech Republic landscape fragmentation is an issue of importance and maintenance of corridors and landscape elements is an important aspect of the Czech nature conservation policy. Not being a part of the nature policy in the 1980s, they have been integrated into the TSES concept in the 1990s as Significant Elements of the Landscape (SLE) and legally recognised (Act 114/1992). They are considered as the “skeleton of ecological stability in the landscape” and are partly legally protected. The non-legally protected elements can change and disappear or be renewed, depending on human intervention or natural processes. Part of the landscape elements support fish and mammal movements.



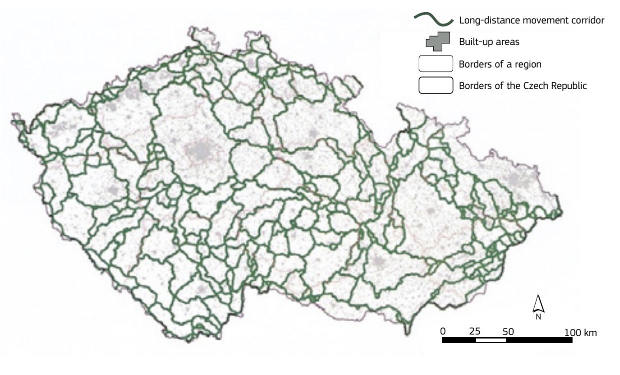


Figure II.36, left
Terrestrial System of Ecological Stability (TSES) for the Czech Republic

Figure II.37, right
Large distance mammal corridors in the Czech Republic

Estonia

In **Estonia**, the roots of nature conservation lie in folk religion. The harsh environment created a strong respect for nature and preservation of the living environment. The nature conservation function of folk religion derived from the closely connected ideas of sacredness and taboo. Because of the vitality of prohibitions and the great number of sacred natural objects, this heritage has been preserved over the centuries. In 1297, the Danish King Erik Menved issued a strict order to prohibit cutting of coastal woods on four islands near Tallinn. The Swedish forest regulations of 1647 and 1664 contained several provisions on forest conservation: ban on cutting of oak, wild apple, rowan and bird-cherry trees. In the beginning of the twentieth century the main focus of activities turned on preservation of natural areas and strengthening of the nature protection movement. The first protected area in Estonia was established in 1910 – a bird sanctuary on the Vaika islands of the West-coast of Saaremaa. The first Nature Conservation Act was passed in 1935.

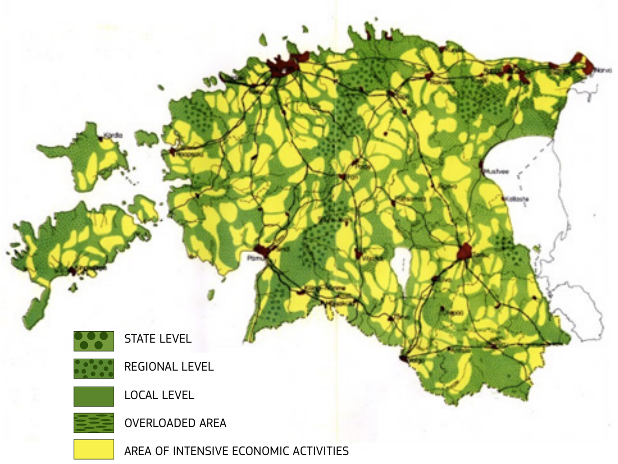


Figure II.38
Network of ecologically compensating areas of Estonia (*Mander et al., 2003*)

At present, the basic frame for nature conservation is set in the Estonian Constitution (1992) stating in Article 5 that: "... natural resources are of national value and they should be used sustainably". Article 53 states, that "...every person shall be obliged to preserve the human and natural environment and to compensate for damages caused by him of her to the environment." In June 1994 the Act on the Nature Conservation Objects (SH 1994, 46, 773) was passed, being one of the main instruments concerning nature conservation. The act is elaborated in several regulations. On March 12, 1997, the Parliament adopted the Estonian Environmental Strategy, which contains following aims on Maintenance of Landscapes and Biodiversity. Tasks set for the year 2010 were among others "to establish a network of nature reserves corresponding to EU recommendations where zones of strict protection (strict nature reserves and special management zones) would cover up to 5% of the terrestrial area of Estonia". The Nature Protection Department of the Ministry of Environment is responsible for national tasks in nature conservation and sustainable use of the earth's surface, environmental management and environmental impact assessment.

The green network is treated both in the Estonian Environmental Strategy (1997) and Environmental Development Plan (1998) and represents the spatial structure of natural areas in the most reasonable way from an ecological, natural, environmental protection and social standpoint. It is also used, in the broader sense as a term of planning, which functionally completes the network of protected areas, connecting them into a complete system with natural areas. In the given areas network communities develop in a natural way, which enhances biodiversity and guarantees environmental stability and social acceptance.

The principles of the ecological network were first applied in Estonia in the 1960s, when it was tried to regulate the use and planning of natural resources. In the years 1979–81 the state ordered "The outline for the protecting and sustainable use of Estonian natural resources" (mapped in a scale 1 : 200 000). The Physical Geography Department of the University of Tartu developed the idea of the ecological network of Estonia, the so-called system of ecologically compensatory areas. These areas were handled as parts of cultural landscape that mitigated the anthropogenic influence on the landscape. The map of Estonian compensatory areas with the explanatory letter was ratified as a basis for planning and developmental action until the year 2005.

Determining the green network was one of the chapters in national planning “Estonia — vision 2010”. It suggested that core areas should be determined on the basis of at least two aspects, area and value. ‘Area’ shows the resistance to anthropogenic influence, and the ‘value’ of the given territory is assessed from the natural and environmental protection point of view (landscapes, prioritised associations and protected species of international importance). Natural regions comprising compact natural territories with the area of at least 100 km^2 were defined as core areas of international importance. Cartographic generalisation shows that such territories form the 12 biggest core areas in Estonia.

‘Compact’ regions with a territory of at least 15 km^2 are defined as core areas of national importance. As areas of national importance are situated in between the areas of international importance, it makes it possible to mark the most important ‘green corridors’ of the network, which constitute convenient dispersal routes for species between the core areas.

Networks of ecologically compensating areas should fulfil the following main ecological and socio-economical functions in landscapes:

» **Biodiversity**. Refuges for species (incl. genetic variability). Migration and dispersal tracts for biota.

» **Material and energy flows**. Material accumulation, recycling and regeneration of resources. Barrier, filter and buffer for nutrient fluxes. Dispersal of human-induced energy.

» **Socio-economic development and cultural heritage**. Supporting framework (e.g., recreation area) for settlements. Compensation and balancing of inevitable outputs of human society (e.g., supporting traditional rural development).

For all three Baltic countries Ecological networks have been developed at the national, regional and local scale. They have been published together under the name coordination of the IUCN office for Central Europe.

France

France has a long history of habitat protection for hunting purposes. Already in 1791, the status of the national forests has been regulated by law. The law of 1922 on production forests also had the aim of protecting soil against erosion. One of the first modern laws with relevance to the protection of areas was the 1930 law relating to the protection of natural monuments and sites of artistic, historical, scientific, romantic or scenic interest. This law was inspired by a previous law of 1913 on historic monuments. The green and blue frame policy in France is a response to the implementation of the pan-European ecological network and is in line with the objectives of the European

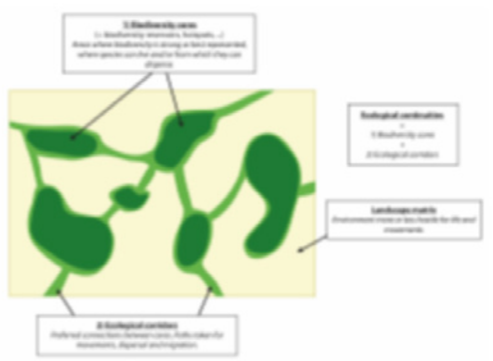


Figure II.39
The French concept the Trame vert et bleu (TVB)

Union biodiversity strategy. Even before the implementation of this policy at the national level, a certain number of communities (regions, departments, natural parks, regional, intercommunal, municipalities) have identified ecological ‘continuities’ and integrated them into their territorial policies and their planning documents. Since 2007, the green and blue infrastructure is one of the major national projects supported by the ‘Ministère de Transition écologique et solidaire’. The main legislative milestones are the law n° 2009-967 on the implementation of the ‘Grenelle de l’environnement’, or the environmental Round Table that brings together state and civil society in order to define new actions for sustainable development. The second law n° 2010-788 on national commitment for the environment proposes and specifies a set of measures intended to preserve biological diversity. It provides, inter alia the basis for the green and blue infrastructure (Trame vert et blue, TVB), an approach that aims to maintain and restore a green-blue network. It aims to halt the loss of biodiversity by preserving and restoring networks of natural environments that allow species to migrate, disperse and interact.

The TVB policy has been launched in 2007 to reduce habitat loss and fragmentation and to integrate biodiversity into urban planning, to support existing EU Nature and Water Directives (Natura2000 and WFD) as a response to the current biodiversity crisis and a way to encourage ecosystem services. The green and blue framework aims to include the preservation of biodiversity in planning decisions, contributing to the improvement of the living environment and the residential and tourist attractiveness. The national parks, nature reserves, biotope protection decrees, Natura 2000 network, regional natural parks focused on the presence of remarkable or endangered species and habitats are essential. However, they have resulted in the creation of islands of unspoilt nature in increasingly artificialized and fragmented territories.

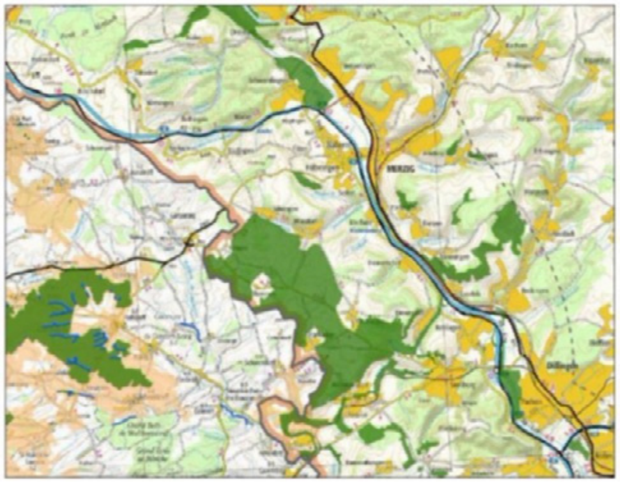


Figure II.40, left
Wooded habitat network at national level.

Figure II.41, right
The ‘Trame vert et bleu’ of Lorraine.

The green and blue infrastructure complements these policies by taking into account the ecological functioning of ecosystems and species in land use planning and relying on ordinary biodiversity. The trame vert et blue consists of five subnetworks, the wooded subnetwork, the open land subnetwork, the wetland subnetwork, the littoral subnetwork and the aquatic subnetwork constituting together the French ecological networks. Based on national guidelines regional and local networks are being developed. Regional ecological networks (REN) were designed with several methods freely chosen by the Regions (e.g. least-cost path). They are mapped at 1:100 000 and accessible in an atlas. Barriers to species movements (roads, dams, other infrastructure) have been identified and plans for actions formulated to preserve or restore the core areas and corridors.

The Netherlands

In **the Netherlands**, the parliament approved in 1990 the Nature Policy Plan (*Natuurbeleidsplan*), in which the long-term nature policy of the government was presented. This policy principally aims at the sustainable conservation, rehabilitation and development of nature and landscape. The government introduced in this policy plan the National Ecological Network (*Ecologische Hoofdstructuur, NEN*). The aim of NEN is to develop a coherent network of natural areas (core areas and nature development areas) that are connected by ecological corridors. With this concept of NEN, the government launched a new approach to nature conservation, replacing the traditional protection of natural areas in their original status, with an active form of protection and nature development, setting clear priorities in a wider (inter)national context.

Figure II.42
National Ecological Network of the Netherlands.

Per 2015, the Netherlands had 66 ecoducts or green bridges. The concept of ‘robust corridors’ was added. The realisation is coordinated by the Multi-year Defragmentation Program (MJPO) which ran from 2005 until 2018. It was decentralised and further planning implementation was handed over to the provinces.

In 2012, during the economic crisis, re-orientation and decentralisation of the national Nature policy took place. The original plan of the NEN was abandoned and aims were reduced to more or less the area that had been realised at that moment. The national agency responsible for land acquisition and the realisation of the NEN through land acquisition was shut down. Also, the realisation of those robust ecological corridors that were not finished was stopped and nature policy was passed over by the national government to the provinces. Most national green bridges were already realised, those plans for corridors and bridges not yet realised were terminated. The NEN changed its name to the Netherlands Nature Network consisting of twelve provincial ecological networks. The provinces continued the national policy with different ambitions and intensities.

Due to it being a strongly urbanised country, nature faces severe pressures in the Netherlands from urban expansion, infrastructure, intensive agriculture and recreation. The Utrecht Hills (Utrechtse Heuvelrug) stretch from north-west to south-east in the centre of the country and consist of several important nature reserves and a national park. This area is dissected by urbanised areas, several motorways and railroad lines, which were making it nearly impossible for fauna to move through the landscape. However, the area is part of the Netherlands Nature Network, and therefore the province of Utrecht and the responsible nature management agencies were mandated to restore connectivity for wildlife.

Figure II.43
The oldest green bridge in the Netherlands over motorway A50 in 1988

Therefore, the owner and manager of transportation infrastructure is responsible for financing and implementing all ecopassages (bridges and culverts); the funds do not come out of the nature conservation budget. This is the main reason why ecoducts and culverts were not implemented in the 1990s. The province's mandate to restore connectivity and lack of actions by the national road authorities (which had an implementation budget) created tensions. Coordination between national and provincial authorities was needed for realizing necessary connecting measures for provincial roads for an optimal return on investments.

A renewed effort was made to speed up the process of landscape defragmentation with the Netherlands Nature Network with extra funds. The province of Utrecht planned priority measures for the Utrecht Hills to improve wildlife movement across national motorways and railroad

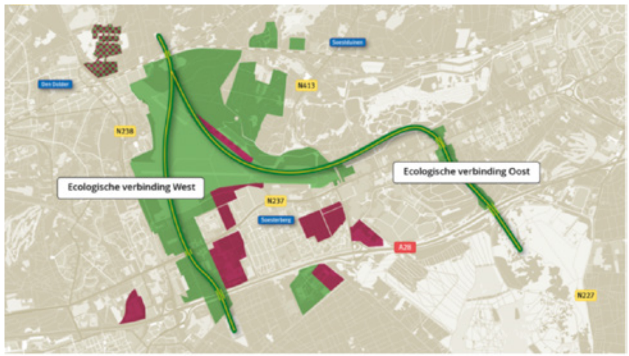


Figure II.44, left
Areas of Connectivity Conservation west and east in the Utrecht hills. The numbers indicate motorways (red) and link roads (yellow). The blue names indicate built-up areas, purple: heathland, green: forest.

Figure II.45, right
Ecoduct Op de Hees, crossing the railroad Utrecht-Amersfoort. A recreational cycle path is situated at the left side of the bridge.

lines. Both the state and the province contributed to the plan by implementing defragmentation measures for the roads under their responsibility. The project “Hart van de Heuvelrug” consists of two main corridors that merge in the north. Whereas the western part is a forest corridor, the eastern ecological part is a heathland corridor. Both corridors contain many small tunnels to cross roads in the area. To realize connectivity, five additional ecoducts have been built in these two areas of connectivity conservation, including the Ecoduct Op Hees, which was completed in 2013 and crosses a busy railroad line between the cities of Amersfoort and Utrecht. In addition to facilitating wildlife movements, it also serves as a recreation corridor, the ecoduct has been made wider to allow cyclists and pedestrians to cross the railway via the ecoduct. This Area of Connectivity Conservation acts as movement routes for mammals (such as roe deer, badger and tree marten) and as a temporary living and breeding area for smaller mammal species.

Annex II: Definitions of used terms

Connectivity: a measure which defines how easily species can move to other habitat patches.

Carrying capacity: the maximum population of a species that a specific ecosystem can support indefinitely without deterioration of the character and quality of the resource, i.e., vegetation or soil.

Dispersal distance: the capacity of most individuals of a species to bridge distances to new potential habitat.

Ecological network: a network constituted of physically separated habitat patches, for a population of a particular species or a set of species with similar requirements that exchanges individuals by dispersal.

Green Infrastructure: GI brings together both the need for strategic planning of green and open spaces and the science of ecosystem services. It promotes the multifunctional nature of space and the benefits that appropriate management approaches can deliver. It recognises the need to plan land use for specific purposes such as farming, nature protection and development but also provides the tool and methods to identify needs and opportunities to enhance the environment and its functions (*John, Neubert, & Marrs, 2019*).

Habitat: an area which can support living organisms for at least part of their life cycle.

LARCH: a landscape-ecological model (acronym for: Landscape ecological Analysis and Rules for the Configuration of Habitat) used to visualise the persistence of metapopulations in a fragmented environment.

Local population: a small population of at least one pair, in one or more habitat patches within the home range of a species. A local population on its own is not large enough to be sustainable.

Local distance: the local distance is the distance covered by a species in its daily movements. This is sometimes called the home range, but home range is usually the area utilized by the species from which you can calculate the local distance.

Metapopulation: a set of local populations in an ecological network, connected by inter-patch dispersal.

Minimum Viable Population (MVP): a population with a probability of exactly 95% to survive 100 years under the assumption of zero immigration.

Network coherence: the spatial coherence of habitat, the network of a species

Network distance (or network gap-closing distance): maximum dispersal distance of a species within non-habitat (e.g., farmland).

Spatial cohesion (landscape connectivity): a relative measure that can visualise the weakest and strongest parts in the ecological network of a certain species.

Viable population: a viable (or persistent) population has a probability of at least 95% to survive 100 years.

CHAPTER B.III.

Co-benefits (ecosystem services) of measures to consolidate the Natura 2000 network

Theo van der Sluis

III.1 Introduction

Humankind is very much dependent on its environment: it provides its food, air, water, energy, it provides inspiration and the sense of place and it sustains biodiversity. These benefits for people are described as 'ecosystem services'. The concept of ecosystem services originated from the early 1970s, but gained increased popularity after publications in the early 1990s (Costanza et al., 1997; De Groot, 1992).

Ecosystem services are increasingly integrated in land use planning. Various countries have incorporated them in their national assessments, following the MAES process which requires countries to make national assessments of Ecosystem services (Maes, Paracchini & Zulian, 2013; Pérez-Soba et al., 2015). The Natura 2000 network, both habitats and species, have an important role in delivering ecosystem services (IPBES, 2018; Ziv et al., 2018).

Ecosystem Services

Ecosystem Services are "*the benefits people obtain from ecosystems. Ecosystem Services include provisioning services such as food, water, timber, and fibres; regulating services that affect climate, floods, disease, wastes, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis, and nutrient cycling*" (*MA, 2005*).

This classification, however, is superseded in IPBES assessments by the system used under "**nature's contributions to people**". This is because IPBES recognises that many services fit into more than one of the four categories. For example, food is both a provisioning service and also, emphatically, a cultural service, in many cultures.

The most commonly used classification of ecosystem services in the EU is: The Common International Classification of Ecosystem Services (CICES). This classification is developed from the work on environmental accounting undertaken by the European Environment Agency (EEA).

Figure III.1
Examples of Ecosystem services
(PBL, WUR & CICES, 2014)

Land-use change is the major direct driver of the loss of both biodiversity and ecosystem services in Europe (*IPBES, 2018*). Natural resource extraction, pollution (nutrients, pesticides and (micro)plastics) and invasive alien species are other major threats. Declining biodiversity is an important risk factor for a constant delivery of ecosystem services during changing conditions (*Vos et al., 2014, Science for Environment Policy, 2015*). For example, man makes use of honey bees for the pollination of orchards, however, wild bees can take over the pollination of orchards at higher wind speeds (*Brittain et al., 2013*). The decline of so many wild species makes our economy, and in particular farming systems, very vulnerable.

Area, spatial structure, abiotic conditions and the age of Natura 2000 habitats are also relevant (*Vos et al., 2014*). In general, Natura 2000 sites in a favourable status deliver more ecosystem services than those in an unfavourable status (*Maes et al., 2012*). Provision and regulating ecosystem services in Natura 2000 sites depend particularly on vegetation structure and land cover, while socio-cultural services and some regulating services depend on particular species (*Bastian, 2013*).

III.1.1 What is the relevance of Ecosystem services for site managers?

Ecosystem services are a tool to improve the link between the site managers on the one hand, and citizens, businesses, policy makers and governments on the other. This could increase the appreciation and understanding of nature and its conservation. It can also strengthen arguments for funding of conservation and restoration measures. However, it is not that easy for the site managers to identify and demonstrate the ecosystem services their site provides.

Often there is not enough knowledge and capacity among site managers to translate the existing scientific knowledge on ecosystem services into practical approaches and factual arguments. This is equally a challenge for deciding on or prioritizing the most appropriate management actions in a management plan; reporting on the benefits of a LIFE project; or communicating ecosystem services to the visitors and the general public.

All measures and management decisions that site managers take can cause possible trade-offs between different ecosystem services (*Schröter et al., 2019*). For example, felling trees may be needed for the restoration of heathland habitat but may reduce the potential of carbon sequestration in that area. Synergies between Natura 2000 measures and ecosystem services are also possible, for instance restoring wetlands can contribute to water regulation and (drinking) water production. Cultural services are often neglected by decision makers or site managers of SPAs. To combine these services successfully with biodiversity goals, beneficiaries should be incorporated into the design and management of the Natura 2000 network (*Science for Environment Policy, 2015*).

The Millennium Ecosystem Assessment concluded that 60% of ecosystem services are being degraded or used unsustainably, often resulting in significant harm to human well-being (*MA, 2005*). A study by *Ziv et al. (2017)* revealed that use of ecosystem services affected bird conservation more negatively by use of water, wild food and recreation in the Mediterranean region than in other European regions. Livestock and fodder production are the most positively featured ecosystem services, especially in Boreal and Alpine SPAs, probably due to extensive land use, while intensive land use in Western Europe leads to negative effects of livestock and fodder production. In Mediterranean countries, agricultural abandonment contributes to carbon sequestration (*Novara et al., 2017*).

The economic value of Ecosystem Services has been estimated to be 223–314 billion Euros per year and far outweigh management costs (*Science for Environment Policy, 2015*). However, balancing costs and benefits is complex as costs are often paid by the community while both communities and businesses benefit from the ecosystem services they provide, and both can contribute to the drivers that put Natura 2000 areas and the services they deliver at risk. A short introduction video to the world's ecosystem services is found here.

Effects of use of ecosystem services on conservation goals also differ between habitats: grazing of livestock and production of fodder and crops have only positive effects in marine/intertidal habitats, but negative impact on agricultural or forest habitats (Table III.1). Regulating services benefit intertidal and heathland habitats, but are a threat for other habitats. The effects of recreation or collecting wild food reveal to be negative in all habitats (*Ziv et al., 2018*):

Table III.1
Examples and synergies and trade-offs, as reported by SPA managers. (*ZIv et al. 2017*)

Impact	Measure
+	fishponds, crops, coastal fields, reforestation, meadows and traditional land use provide bird habitat
+	reforestation increases carbon sequestration and (on flood plains) water retention
+	hunting prevents damage to forest by reducing game animals and anglers help to protect food sources
-	intensive aquaculture and agriculture reduces or damages nesting and food habitat
-	fibre or wood production can lead to invasion of exotic trees and/or disturbance or loss of habitat
-	conversion of natural habitat into multifunctional or agricultural habitat causes habitat loss
-	water energy plants or flood defences disturb fluvial ecosystems and cause noise pollution
-	recreation disturbs birds and habitats, ammunition of hunters poisons birds of pray

In the paragraphs below the opportunities and trade-offs for restoration of rivers and wetlands and coastal habitats are presented. Paragraph III.4 presents the relation between ecosystem services and climate measures, while III.5 has a focus on the relation between ecosystem services and Natura 2000 connectivity restoration measures. At the end key findings and recommendations, and suggestions are made for websites or organisations that can provide further information.

III.1.2 Policies and Ecosystem Services

Ecosystem services are implicitly mentioned by Action 5 of the EU Biodiversity Strategy 2020. In particular Target 2 requires the restoration of at least 15% of degraded ecosystems to sustain the supply of services (*European Commission, 2011b*). Also the EU Biodiversity Strategy 2030 emphasizes the the "protection and restoration of biodiverse areas with high ecosystem services and climate mitigation potential (*European Commission, 2020*).

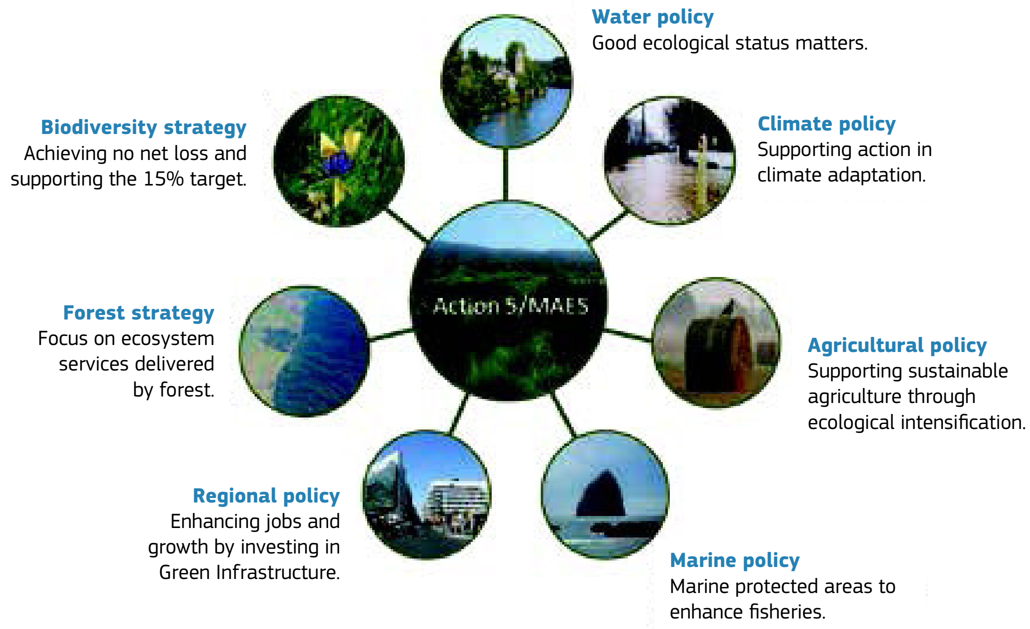


Figure III.2

Example to illustrate inputs of Action 5 into other policies (*Maes et al. 2014*)

The Biodiversity Strategy 2030 mentions specifically its increased support for the IPBES process. It underlines the importance of conserving and restoring land rich in ecosystem services (*European Commission, 2020*).

Ecosystem service maps can help to identify areas of high potential for ecosystem services delivery or for demand for ecosystem services, as well as where possible conflicts may occur. Information on ecosystem services is essential for developing comprehensive and strategic development plans (*Albert, Geneletti & Kopperoinen, 2017*).

The Commission's Communication on Green Infrastructure (COM(2013) 249), explains its principles and promotes investments within and outside Natura 2000 and other protected areas. It defines Green Infrastructure [see Chapter B.II] as "a strategically planned network of natural and semi-natural areas but also other environmental features designed and managed so as to deliver a wide range of ecosystem services."

Mapping and assessment of ecosystem services is not only important for advancement of biodiversity objectives, but is strongly related to the implementation of other related policies, including water, marine, climate, agriculture, forestry as well as regional development (*Burkhard & Maes, 2017*; *Maes et al., 2014*) (Fig. III.2). Ecosystem service mapping and assessment results can support sustainable management of natural resources, to be applied in development of nature-based solutions, contribute to spatial panning as well as environmental education.

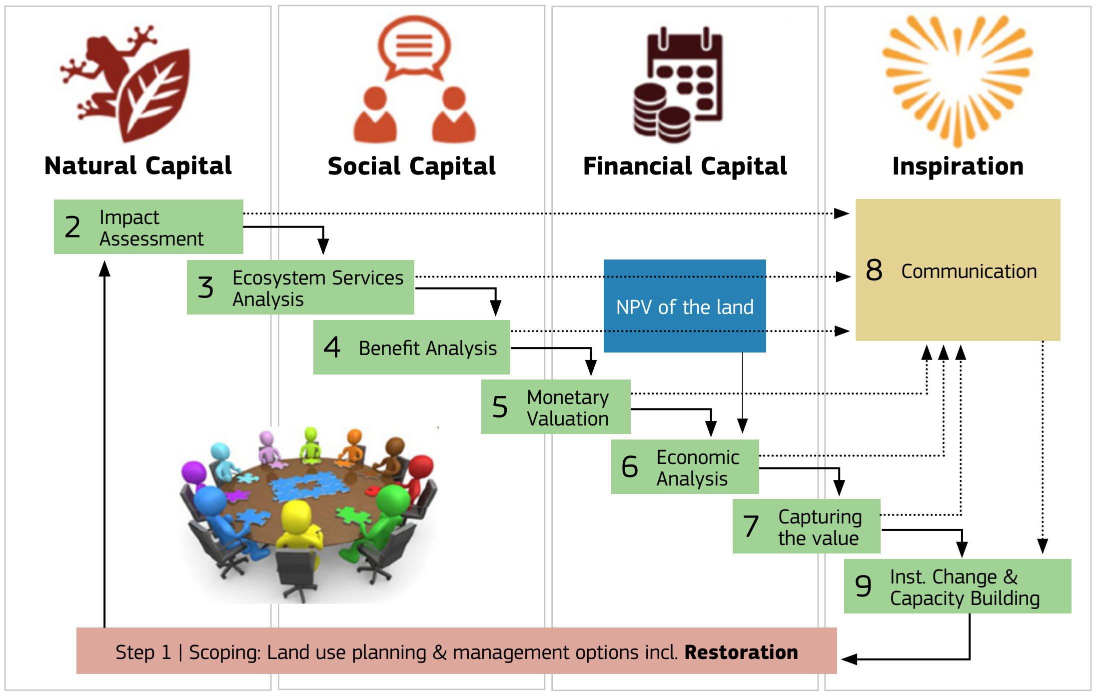
A webinar organised by the OPPLA project on how ecosystem services are included into policy can be found at: oppla.eu/did-you-miss-operas-webinar-how-ecosystem-services-included-policy.

III.1.3 Tools

There are many tools and approaches for an integrated ecosystem services assessment, such as InVEST (WWF, Stanford), TESSA (Birdlife International, WCMC) or Grace (IUCN), to mention a few. The approach presented here is from the Ecosystem Services Partnership, which is a network that connects 3000 people and 45 organizations from more than 70 countries (www.es-partnership.org).

The aim of the ESP is to enhance the policy and practical application of ecosystem services for conservation and sustainable development.

The approach developed by ESP consists of nine steps (Figure III.3), supported by Annexes with specific information on how to implement each step. Both the Guidelines and supporting material are 'living documents' that will be further improved and updated in subsequent versions.



The 9 steps in the Framework for integrated ecosystem assessment and the Guidelines are briefly explained below

1 Scoping: Before starting an assessment, the scope, context and purpose of the assessment should be made clear, in close consultation with the most relevant stakeholders, to avoid collecting unnecessary data or forgetting important aspects.

2 Impact Assessment: this step involves assessing the direct impacts (positive and negative) of restoration or other interventions on the landscape, on ecosystem structure & processes (vegetation, runoff) as well as the secundary effects in terms of changes in the functioning of the landscape (i.e. the (carrying) capacity of the landscape to provide services) compared to the baseline (e.g. loss of vegetation leading to erosion and loss of productive capacity).

3 Ecosystem services analysis: effect (of restoration or other intervention) on changes in actual, and potential, use of specific ecosystem services. E.g. planting trees will reduce erosion (see step 2) thus enhancing the capacity of the landscape to provide resources (eg. wood, fruit), clean the air, provide habitat for biodiversity and increase aesthetic quality possibly providing more recreational benefits. On the other hand, it might negatively affect water availability for irrigation or consumption. Thus, the total bundle of ES should be taken into account, including trade-offs, when analysing the return of Natural Capital.

4 Benefit analysis: changes in ES as analysed in Step 3 will have effect (positive or negative) on health, livelihood, cultural identity, and other wellbeing (social & human-capital) indicators (e.g. jobs, education, security, social-cohesion). In this step these benefits are quantified in non-monetary terms. *(continues on the next page)*

Figure III.3
ESP Guidelines for Integrated Ecosystem Assessment
www.es-partnership.org/esp-guideline
(*De Groot et al. 2018*)

III.2 Ecosystem services from rivers and wetlands

III.2.1 Potential and opportunities

Under natural conditions, biodiversity hotspots are often found near rivers, their banks and floodplains. Rivers and surrounding areas represent habitats with high levels of structural and functional dynamics, primarily induced by downstream flow (*Ward et al. 1999*). Hydrological, biogeochemical and ecological functions of river ecosystems provide a set of well-known ecosystem services. In particular, flood regulation (regulating), fresh water (provisioning), nutrient cycling (supporting), recreation (cultural), habitat functions for aquatic species (partly for food, fish production), transport functions (ship traffic), among others. When ecosystems are maintained in good ecological condition, their ability to provide these services is greater, while the deterioration of aquatic ecosystems may reduce the viability of the provided services. Intact river ecosystems are more effective at processing nutrients, breaking down waste, filtering water and providing habitats for fish (*Garcia & Honey-Roses, 2014*).

However, the large majority of rivers are influenced, and to a large extent, regulated, by humans. Most floodplain areas have been hydrologically disconnected from the river by the construction of dykes, and are currently often dominated by intense human use, such as agriculture, settlements or traffic routes (*Schindler et al., 2016*) and Europe is the continent that is most affected by such activities (*Nilsson, Reidy, Dynesius, & Revenga, 2005*). Also dam construction has heavily impacted streams, e.g. in Spain, Italy and the Balkans but also in Scandinavia (*Schwarz, 2019*). Often the ecosystem services have declined as a result, or instead of providing a multitude of services these have been narrowed down to just few services (e.g. boat traffic).

River restoration can restore the river to a more natural state, with an increase in ecosystem services as a result. This is in line with the Water Framework Directive which requires countries to take measures to improve the state of the water bodies. In particular floodplain wetlands provide many ecosystem services, and restoration of rivers may increase the resilience of the system while increasing also the various ecosystem services. Ecosystem services of floodplain wetlands were priced nearly ten times higher than the value we calculated for rivers (*Szałkiewicz, Jusik, & Grygoruk, 2018*). With smart measures aimed at a multitude of services, the costs of river restoration often can be offset against the benefits and services that are provided by more intact rivers and wetlands.

A review was prepared by *Stefan Schindler et al. (2014)* of hundreds of articles on floodplain interventions (38 in total) as well as the impact of restoration measures on its service delivery potential (Annex 1). This shows for example that removal of river bank fixations (measure 7) has positive effects on 12 ecosystem services, negative only for 'terrestrial plants/animals for food, biomass based energy, and in some cases mixed effects such as control of invasive species (Annex 1). This table gives an indication of measures that could therefore be considered for river and wetland restoration.

5 Monetary valuation: once we understand, and preferably quantified, the effects of land use change (e.g. restoration) on ecosystem services (step 3) and … … benefits (step 4) we can analyse the monetary effects using direct market values, indirect market values and non-market values to determine changes in Total Economic Value of the bundle of ES provided by the restoration activities. If so desired, the TEV can be used to calculate changes in the Capital or Net Present Value (NPV) of the land after restoration (or other land use change measures).

6 Economic analysis: this step investigates the implications of ecosystem restoration for the local/regional/national economy in terms of economic indicators, e.g. employment, increased tax revenues, corporate profits, return to investors, etc. Also the change (usually increase) in value (NPV) of the land (see step 5) should be part of the economic analysis.

7 Capturing the value: based on steps 5 and 6, which together provide information on the return of financial capital, incentives (financial or otherwise) can be developed to invest in ecosystem restoration and/or sustainable management.

8 Communicating the value (and benefits) to generate awareness and support ('inspiration') for the measures needed to implement the incentives, communication activities can be employed after any of the steps (e.g. simply providing information on the return of ecosystem services (step 3) and their benefits (step 4) might be enough to move to step 9 (changing institutions and behaviour) without having to go through the more complicated and time-consuming efforts to calculate monetary (step 5) and economic (step 6) effects.

9 Capacity building and institutional change: to ensure implementation of the outcome of the assessment in long term policy, institutional and management changes at relevant scale levels (e.g. ranging from local capacity building programs to national policies and institutions) are needed.

III.2.2 Example studies

Room for the river

The Dutch floodplains were dominated for centuries by farming and water management (water safety measures). In the Netherlands, the approach towards climate change and coping with floods has changed over the last two decades. Now, the overall aim is to increase multifunctionality, with flood protection and increasing biodiversity being among the most important functions, another important function is tourism.

In 2007 the Government approved the Room for the River Programme for the Rhine. This plan had three objectives:

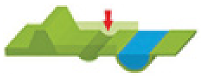
- **i** by 2015 the branches of the Rhine must be able to cope with a discharge capacity of 16,000 m^3/s without flooding;
- **ii** the measures implemented to increase safety must also improve the overall environmental quality of the river region; and
- **iii** the additional retention area for the river, required to cope with higher discharges, will remain permanently available for this purpose.

With all large projects implemented, the program was officially finalized in 2019.

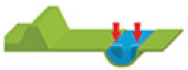
A catalog of measures for floodplain restoration: Room for the River

Based on experiences in nature restoration, combined with hydrology needs, various floodplain restoration options were developed for the program 'Room for the River'.

In total, nine options are considered to enlarge riverbed and floodplains, including dyke relocation, depoldering, and water storage (Fig. III.3). This catalog of options has been applied in 39 projects along the river Rhine and its tributaries (read more here and here). Similarly, a restoration program was done for the river Meuse.

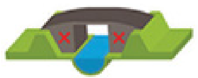


Lowering floodplains
Loweing/excavating part of the floodplain increases room for the river in the high water situations.

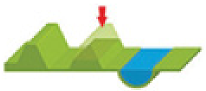


Lowering groynes
Groynes stabilise the location of the river and ensure its correct depth. However, in a high water situation, groynes may obstruct the flow to the river. Lowering groynes speeds up the rate of flow.

Dyke relocation
Relocating a dyke inland widens the floodplain and increases room for the river.



Removing obstacles
If feasible, removing or modifying obstacles in the riverbed will icrease the rate of flow.

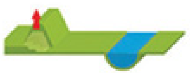


Depoldering
The dyke on the riverside of a polder is lowered and relocated inland. This creates space for excess flows in extreme high water situations

Water storage
The Volkerak-Zoommeer provides temporary water storage in extreme situations where the storm surge barrier is closed and there are high river discharges to the sea.

Deepening summer bed
Excavating/deepening the surface of the riverbed creates more room for the river.

High water channel
A high water channel is a dyke area branching off from the main river to discharge some of the water via a separate route.



Dyke reinforcement
Dykes are reinforced at given locations where river widening in not feasible.

Figure III.4

The nine options considered to enlarge riverbed and floodplains in the Netherlands. This catalog of options has been applied in 39 projects along the river Rhine and its tributaries.

Measure	No. of projects (Rhine & Ijssel)	Expected impact				
		Multifunctional use	Biodiversity	Natural dynamics	Landscape diversity	Flood protection
Dyke relocation	5	0	+	+	±	+
Excavation of the floodplain	12	+	+	+	+	+
Depoldering	2	-	+	+	±	+
Lowering of the summer bed	1	0	0	0	±	+
Lowering the groynes	3	0	0	0	0	+
Removing obstacles	1	0	0	+	±	+
Water storage	1	+	0	0	0	+
High water channel	1	-	0	0	-	-
Dyke improvement	7	0	0	0	-	-

Table III.2

Impacts of the different measures of the Dutch 'Room for the River' Programme on multifunctional use, biodiversity, natural dynamics, and flood protection.
(Schindler, O'Neill et al. 2016)

The mixed centralized-decentralized approach in the Netherlands has been effective though in realizing many water safety projects through the stakeholders involved, partly funded through industries. However, stakeholders views and public support have been questioned (*Fliervoet et al., 2013*).

The various measures were evaluated towards the expected impact of the measures on various parameters, including biodiversity, natural dynamics and landscape diversity (Table III.2). The most beneficial measures are dyke relocation, excavation of the floodplain and depoldering (*Schindler et al., 2016*).

There is a window of opportunity to promote further the establishment of multifunctional flood-plains due to the public attention generated by an increasing number of devastating floods in Europe, which underlines the failure of monofunctional approaches, and by the enhanced inter-est and take up of the concepts of ecosystem services and multifunctionality by recent policies (e.g. policies to support Green Infrastructure across Europe).

III.2.3 Meeting Water Framework Directive objectives and the Nature Directives

The Nature directives have many synergies with the Water Framework Directive (WFD). The main objectives of the WFD for surface waters are **1)** to prevent the deterioration of any status, **2)** to reach good ecological status and good chemical status as a rule by 2015, and **3)** to implement all necessary measures to reduce pollution. This refers to all surface water bodies, including those that form part of a Special Protection Area (SPA) under the Birds Directive and/or a Site of Community Importance (SCI) under the Habitats Directive. For groundwater the objective is to reach good quantitative status and chemical status of all underground water bodies.

Figure III.5
Baume-les-Messieurs, Natura 2000 site with vineyards situated between the limestone cliffs with important habitats and protected species like peregrine falcon.
© Theo van der Sluis

The WFD clearly mentions the protection and enhancement of the status of aquatic ecosystems and with regard to their water needs also the protection of terrestrial ecosystems and wetlands directly depending on them (Article 1). The WFD stipulates the establishment of a register of protected areas "which have been designated as requiring special protection under specific Community legislation for the protection of their surface water and groundwater or for the conservation of habitats and species directly depending on water". The register must contain "areas designated for the protection of habitats or species where the maintenance or improvement of the status of water is an important factor in their protection, including relevant Natura 2000 sites ..." (Annex IV, (v) WFD).

Any Natura 2000 site with water-dependent (ground- and/or surface water) Annex I habitat types or Annex II species under the Habitats Directive or with water-dependent bird species of Annex I or migratory bird species of the Birds Directive, and, where the presence of these species or habitats has been the reason for the designation of that protected area, has to be considered for the register of protected areas under WFD Art. 65. These areas are summarised as "water-dependent Natura 2000 sites". For these Natura 2000 sites, the objectives of the BHD and WFD apply (*European Commission, 2011a*).

There can be many common issues for both directives, dealing with water. There are therefore potential benefits to approaching the directives together. An example of such joint approach is the 'grip on life project', in Sweden. The purpose of the project is to increase the understanding of the two directives, defining whether objectives are in conflict or not, identify the most stringent objective, identifying common measures and actions. They did a study of the similarities and relations between the directives to define actions that would enhance river restoration and ecosystem services. Even if there are differences between the two directives, there are synergies and in many cases the objectives and measures coincide.

III.3 The services of coastal habitats

III.3.1 Introduction

Coastal habitats are hotspots of biological production and diversity in the landscape (*IPBES, 2018*). Some 40% of the Western European population is living in coastal areas (*IPBES, 2018; Schröter, Bonn, Klotz, Seppelt, & Baessler, 2019*). This has affected the services these systems provide, due to infrastructure development, pollution, habitat loss and overexploitation. Due to environmental policies coastal eutrophication has decreased but the proportion of marine dead zones near European shores has increased and the ecological status of many coastal areas are still unfavourable. In some coastal habitats the goal of conservation of at least 10 percent of coastal and marine habitats by 2020 has been reached (*IPBES, 2018*). Also the introduction of exotic species like the Pacific oyster has led to invasion of blue mussel beds. Moreover, coastal areas are at risk due to climate change induced sea level rise and increasing weather extremes. Consequently, the number and size of hard sea defences have increased, decreasing natural processes of dune succession and levelling of tidal movement, exhausting the natural sand supply along the coast.

Nature-based solutions are being increasingly used in maintaining or restoring some of the key ecosystem services provided by coastal areas. Nature-based solutions can contribute both to restoration of Natura 2000 sites and increasing ecosystem services. Nature-based solutions can increase coastal resilience by protecting communities against extreme events such as storms and stabilizing shorelines against water erosion. Furthermore, the use of multifunctional nature-based solutions in coastal areas can provide a range of other economic and cultural values.

Integrated natural resource management and integrated coastal zone management offer opportunities to combine efforts to meet different planning goals along the coast.

III.3.2 Coastal defence: the 'sand-motor' project

One of the large-scale projects of 'building with nature' is the Dutch 'sand motor project' . Every year, for many decades, the sea would erode the Dutch coast. The water authorities had to replenish the shortfall by depositing sand on the beaches and in the offshore area. This was vital to avoid flooding of the lower lying coastal zones and urbanized areas in the Netherlands. The sand replenishment operations had to be repeated every five years, and due to sea level rise there was an increased need to find alternative options to protect the coast in a more sustainable and natural way.

The solution was the creation of what is called the Sand Motor (also known as Sand Engine). This is a peninsula on the coast near The Hague, constructed with a large volume of sand.

Nature-Based Solutions

Nature-based solutions (NBS) are defined by the IUCN as "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits".

However, more than one definition and interpretation of NBS exists and it also depends on the context in which it is used. In the context of climate change NBS means: an effective, long-term and cost-efficient approach to tackling climate change. These practices can protect natural resources while improving the state and quality of our ecosystems. NBS are an essential part of the overall global response to climate change and sustainable development.

In principle, NBS mimics natural processes and builds on fully operational water-land management concepts that aim to simultaneously realize goals, e.g. to improve water availability and quality and raise agricultural productivity, or coastal defence measures and restoration of coastal wetlands;

There is no straightforward distinction between NBS and other human induced management of ecosystem services.

Between March 2011 and November 2011, the water authorities and the provincial authority of Zuid-Holland created the hook-shaped peninsula. It extended 1km into the sea, and it is 2km wide where it joins the shore. Hopper dredgers picked up the sand ten kilometres off the coast and deposited it at the peninsula and two replenishment locations alongside the peninsula which are also part of the Sand Motor.

Figure III.6
An aerial view of the 'sand motor project', showing the artificial sand deposition along the Dutch coast near The Hague. © Rijkswaterstaat: dezandmotor.nl/fotos-en-videos

The sea will erode gradually the deposited sand of the peninsula and spread the sand along the coast. This stops further coastal erosion. The approach has been very successful, and the coastal defences are now at maximum strength.

The Sand Motor is open for recreational purposes. Visitors are able to ramble over the enormous sand shoal. Seals may also be present on the Sand Motor. Of course, nature – young dunes for example – needs time to develop. This project therefore provides opportunities for important Habitats such as 2130* grey dunes, 2110 embryonic shifting dunes, 2120 white dunes and 2190 humid dune slacks (see also *Houston, 2016*).

The Sand Motor is a great example of building with nature. By depositing a large amount of sand in a single operation, the repeated disruption of the vulnerable seabed is avoided. Nature takes the sand to the right place, and the expectation is that no further sand replenishment is required for the next 20 years.

The Sand Motor is the first experiment of its kind. In fact, it is 'working with water', instead of against it. The concept can be applied in other areas in the Netherlands and the rest of the world.

III.4 Climate and ecosystem services

The Natura 2000 network holds a large proportion of Europe's natural and semi-natural ecosystems that provide a wide variety of ecosystem services. Many of these Natura 2000 habitats do deliver several climate services: carbon storage, temperature and drought reduction, reducing risks of sea level rise and extreme weather events, (fires, floods), and water retention (*Bouwma et al., 2012*). At the same time, coastal habitats, freshwater habitats, bogs, mires, fens and alpine habitats are vulnerable to climate change.

The EU Biodiversity Strategy calls therefore for a strict protection of all the EU's remaining primary and old-growth forests. Also, the Commission will "put forward a proposal for legally binding EU nature restoration targets in 2021 to restore degraded ecosystems, in particular those with the most potential to capture and store carbon" (*European Commission, 2020*).

Adaptive management and no regret measures in Natura 2000 sites can be part of the solution, climate change needs to be an integral part of all (policy) sectors. In the Netherlands for instance, Natura 2000 legislation overrules climate policy. (National) legislation on Natura 2000 and climate could be integrated by introducing an overruling legal instrument on sustainability as has been introduced in New Zealand (*Kistenkas & Bouwma, 2018*).

Most Natura 2000 restoration measures have synergies with ecosystem services, but trade-offs may occur when one of the following aspects are not properly taken into account:

» Interactions between ecosystem services (including interactions with biodiversity): complex interactions between restoration measures and ecosystem services, e.g. water purification of target water areas may lead to pollution of other (downstream) waters.

» Forest management targeted to carbon conservation only, may lead to biodiversity loss, or vice versa. Climate smart forestry or a combined strategy, however, may protect carbon stocks and biodiversity better, compared to one management strategy (*Thomas et al., 2013, Nabuurs et al., 2017*). The central issue in this combined strategy is to prioritize biodiversity in a set of different ecosystems with different sets of (target) species. However, this works best for localised, small-range species, well-represented in habitats at the end of the abiotic gradients, such as high latitude and coastal areas.

» (Bundles) of ecosystem services: biodiversity targets and several services should be targeted together (*Bullock et al., 2011*). Different habitat types can deliver different bundles of ecosystem services and biodiversity. Whether synergies or trade-offs exists between restoration measures and ecosystem services depends on the specific bundle under consideration and on the scale level.

» Spatial scale: for some ecosystem services it is important that service provision is arranged at a global level, like carbon sequestration, some at a regional level, like flood prevention and some at a local level, like leisure and air quality (*Verhagen, 2019*). Restoration measures may lead to synergy with local ecosystem services, but trade-offs at other locations, e.g. when considering heterogeneity in Alpine landscapes (*Crouzat et al., 2015*) or in river catchments (*Verburg et al., 2012*). When considering buffer zones, creating buffer zones located outside protected areas may lead to synergies, e.g. with recreation, while creating buffer zones inside protected areas leads to trade-offs (e.g. *Palomo et al., 2013*). Landscape structure seems to have a positive effect on ecosystem services mainly at the local level (*Verhagen, 2019*). For site managers the landscape scale might be the appropriate level, and one might consider the use of 'landscape services' for that matter (*Van der Sluis et al., 2018*).

» Beside the aspect of spatial scale, time scales are also important to preserve the reliability of the provision of ecosystem services. Just as in targeting Natura 2000 goals, biodiversity is a crucial factor for both effectiveness and reliability of ecosystem service provision (*Vos et al., 2014*).

ESS restoration measures Natura 2000	carbon storage / capture	temp/ drought reduction	reducing risks sea level rise and extreme weather events (fire, floods, erosion)	water retention/ purification	recreation value
reduction of pressures					
improving hydrological conditions	+	no info	no info	-	-
reduction of acidification / eutrophication	+ and -	+	+	+	+
ensure good abiotic conditions	~~ reducing existing pressures				
manage extreme events	~~ reducing risks				
increase size	+ and -	+	+	+	+
create buffer zones	+	no info	+	+	+ and -

Table III.3
The impact habitat management and habitat restoration measures, and the various climate services that the Natura 2000 site can provide. + positive impact, - negative impact (*Bouwman et al., 2012*)

» The location where measures are taken: e.g. the bufferstrips on fields should be located where influx of pollution is likely, and measures that increase water retention are effective upstream to prevent floods downstream. For some ecosystem services it is crucial to take measures where the demand is, and that is often not in or near protected nature areas, but in agricultural (pollination, natural pest regulation, water purification) or urban areas (leisure, air quality) (*Verhagen, 2019*).

III.5 Ecosystem services and network coherence

Associated ecosystem services with landscape connectivity restoration measures
Based on measures for defragmentation and development of Green Infrastructure, the provision of ecosystem services may change. Selected ecosystem services for this assessment are related to Provisioning services, Regulating and Maintenance services, and Cultural services. Although this selection might be challenged to be subjective, the selected services are relevant in the wider European context and commonly used in other studies, and selected services may change as a result of landscape changes or measures for GI (*Bürgi et al. 2015*; *Vallés-Planells et al. 2014*). To estimate how the service provision changes as a result of measures to improve connectivity through GI, a semi-quantitative approach has been used (Table III.4) (*Van der Sluis & Bouwma, 2019*).

The results are related to the examples of habitat restoration and restoring connectivity as described in the chapter B.II Green Infrastructure.

Service Provision	Example study					
	Boreal Baltic Meadows (H1630)	Alpine Rivers (H3230)	Eurasian lynx	Stag beetle	Sturgeon	Large copper
Cultivated crops (CC)	○	○	-	○	○	○
Reared Animals (LSU)	++	+	-	○	○	○
Wild animals and their output (WI)	+	○	-	○	++	+
Materials from timber (MT)	○	○	++	-	○	○
Plant-based resources (PR)	++	○	+	○	○	++
Erosion protection (EP)	++	++	+	○	++	○
Climate regulation (CR)	+	○	++	++	○	++
Flood Protection (FP)	++	++	+	○	++	++
Pollination and seed dispersal	++	+	+	+	+	+
Maintenance of Nursery Populations and Habitats (NS)	++	++	++	++	++	++
Outdoor Recreation (RC)	+	++	++	+	++	++
Residential (RE)	+	○	○	○	○	○
Inspiration (IN)	++	++	++	++	++	+

Table III.4
Quantitative assessment of change in landscape service provision in study areas: + increase, ++ : strong increase, - decrease, -- strong decrease, ○ negligible. The cases are described in Chapter B.II and *Van der Sluis & Bouwma (2019)*

III.6 Key findings and recommendations

Co-benefits of measures to consolidate the Natura 2000 network are interwoven with all themes covered in this E-BIND handbook. Whether it is the use of remote sensing, (advantages of) habitat restoration or Green Infrastructure, it all is related to benefits of proper management of resources, proper management planning, 'keeping stock' of resources and development of species and habitats.

Ecosystem services are a fast developing field. However, the applicability of ecosystem services is not always straight-forward, and frequently it is rather theoretical in nature, of little use at site level.

However, ecosystem services can be important because they can be quantified and used for planning. A good selection of indicators can be a good proxy for ecosystem functioning. It is important though to make sure that a wider range of indicators is used, here

Figure III.7
Agricultural crops are important provisioning services.

the hierarchical structure of CICES can be used to aggregate ecosystem services to a higher level for which suitable indicators may be available.

Ecosystem services also have shortcomings: economists tend to approach everything in monetary terms, and particular services are not easily assessed in this way (e.g. cultural heritage, landscape value), these might easily be missed in assessments. Moreover, in cultivated areas or well-studied regions one might easily quantify outputs of the system, whether it is crops, timber or water. However, it will become much more complex to attach such figures to e.g. natural maquis in Southern Europe, or to arctic tundra. Over time, more data will become available, and more tools will be developed to fill such gaps in knowledge.

With IPBES' 'nature's benefits to people' have been properly founded in international conservation planning, which are extremely important now for international discussions and negotiations e.g. at the CBD. Ecosystem services will therefore remain in site management and conservation planning. Ecosystem services are important for communication: with the 'public', site users, communication with politicians, or with decision makers. Ecosystem services and 'co-benefits of nature for society' can be used to justify the investment of capital and other resources. As such, it can support the site managers.

This chapter has provided a number of practical examples, such as co-benefits of habitat restoration, Table III.4 and Annex I.

III.7 Further sources of information

Eurosite has formed the 'Eurosite economics and Ecosystem Services Working Group'. They have produced a brochure with an introduction to ecosystem services for site managers, which can be found at the following site:
www.eurosite.org/wp-content/uploads/ESS-brochure-v06-WEB-1.pdf

MEDWET, the Mediterranean Wetlands Initiative has a Specialist Group on ecosystems services (**MedWet/STN/Ecosystem services-SG**). This specialist group has produced a short brochure on the services of Mediterranean wetlands which can be found at:
medwet.org/publications/the-ecosystem-services-of-mediterranean-wetlands-medwet-stn/

WEBINARS on Ecosystem Services can be found at:
Optimizing Restoration Activities for Ecosystem Services: The Restoration Opportunities Optimization Tool (ROOT) is at: vimeo.com/261376393

Ask **OPPLA** is a crowd-sourced enquiry service. It's designed to help you find the information you need about nature-based solutions. oppla.eu/ask-oppla

In the wealth of existing publications, a good basis for any work on ecosystem services form the reports from J. Maes, e.g. *Maes et al. (2013, 2014, 2018)* and *Burkhard & Maes, 2017*.

Best practices/websites:

country	measure	link
global	international platform on biodiversity and ecosystem services	www.ipbes.net
global	natural climate solutions	nature4climate.org
global	partnership on ecosystem services	es-partnership.org
the Netherlands	building with nature solutions	www.ecoshape.org/en
Portugal	LIFE project Pronatur	www.nortenatur.cimaa.pt
UK, the Netherlands, Belgium	INTERREG project building with nature	northsearegion.eu/building-with-nature
the Netherlands	maps of ecosystem service providing areas	www.atlasnatuurlijkkapitaal.nl
Europe	knowledge platform on ecosystem services and natural capital, developed by the EU project openness	oppla.eu/ask-oppla www.openness-project.eu
Europe	topic ecosystem services on BISE platform (biodiversity information system for Europe)	biodiversity.europa.eu/topics/ecosystem-services
the Netherlands	knowledge network for restoration and management of nature in the netherlands	www.natuurkennis.nl/english
UK	restoration of Fen habitats	www.greatfen.org.uk/restoration/habitats

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Annex 1: Overview of the expected effects of 38 floodplain interventions on the supply of 21 different ecosystem services

(derived from the paper from: *Schindler et al., 2016*)

Type of intervention	Intervention	Terrestrial plants and animals for food	Freshwater plants and animals for food	Water for human consumption	Water for agriculcural use	Water for industrial and energy use	Biotic materials	Biomass based energy	Bioremediation	Dilution and sequestration	Air flow regulation	Water flwo regulation	Mass flow regulation	Atmospheric regulation	Water quality regulation	Pedogenesis and soil quality regulation	Lifecycle maintenance, habitat and gene pool protection	Pest and disease control (incl. invasive alien species)	Aestetic, heritage	Spiritual	Recreation and community activities	Information and knowledge
1	Surface water extraction	↘↗	↘	↘↗	↘↗	↘↗	↘	↘↗	↘	↘	0	↘↗	↘	↘	↘	↘	↘	↘↗	↘	↘	↘	↘↗
1	Groundwater extraction	↘↗	↘	↘↗	↘↗	↘↗	↘	↘↗	↘	↘	0	↘	0	↘	0	↘	↘	0	0	0	0	0
1	Mineral resource extraction	↘	↘↗	↘	↘↗	0	↘	↘	↘	↘	0	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘↗	↘↗
2	Settlement and traffic infrastructure	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	0	↘	↘	↘	↘	↘	↘	↘	↘	↘
2	Energy conversion	↘	↘	↘	↗	↗	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘↗	↘↗
2	Navigational infrastructure	↘	↘	↘	↘	↘	↘	0	↘	↘	0	↘	↘	0	↘	↘	↘	↘	↘	↘	↘↗	↘
3	Forestry intensive	↘	↘	↘	↘	↘	↘↗	↗	↘	↘	0	↘	↘	↘↗	↘	↘	↘	↘	↘	↘	↘	↘
3	Agriculture intensive	↗	↘	↘	↘	↘	↘↗	↗	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘
3	Fishery intensive	↘	↘↗	↘	0	0	↘	0	0	0	0	↘	↘	0	↘	0	↘	↘	↘	↘	↘	↘
4	Forestry extensive	0	0	0	0	0	↗	↗	0	0	0	0	0	0	0	0	↘	0	0	↘	↗	↘↗
4	Agriculture extensive	↗	0	↘	0	0	↗	0	0	0	0	0	0	0	0	0	↘↗	↘	↘↗	↘	↗	0
4	Fishery extensive	0	↗	0	0	0	0	0	0	0	0	0	0	0	0	0	↗	0	↗	↗	↗	↗
4	Hunting	↗	0	0	0	0	↗	0	0	0	0	0	0	0	0	0	↘	↘↗	0	↘	↘↗	0
5	Channel correction	↘↗	↘	↘	↘	↘	↘↗	↗	↘	↘	0	↘	↘	↘	↘	↘↗	↘	↘	↘	↘	↘↗	↘
5	Dike construction	↗	↘	↘	0	↗	↗	↗	↘	↘	0	↘↗	↘	↘	↘	↘	↘	↘	↘	↘	↗	↘↗
5	Band/bed stabilization	↗	↘	↘↗	↘↗	↘↗	↘↗	↗	↘	↘	0	↘	↘	↘	↘	↘↗	↘	↘	↘	↘	↘↗	↘
5	Sediment removal/dredging	0	↘	↘	↘	↘	0	0	0	↘↗	0	↘	↘	↘	↘↗	0	↘	0	0	↘	↘↗	0

Table III.5

The judgements are based on expert opinion. "0": no effect; "↘": reducing effect; "↗": supporting effect; "↘↗": ambiguous effect, i.e. reducing or supporting depending on the environmental conditions. (*Schindler et al., 2014*)

Type of intervention	Intervention	Terrestrial plants and animals for food	Freshwater plants and animals for food	Water for human consumption	Water for agriculcural use	Water for industrial and energy use	Biotic materials	Biomass based energy	Bioremediation	Dilution and sequestration	Air flow regulation	Water flwo regulation	Mass flow regulation	Atmospheric regulation	Water quality regulation	Pedogenesis and soil quality regulation	Lifecycle maintenance, habitat and gene pool protection	Pest and disease control (incl. invasive alien species)	Aestetic, heritage	Spiritual	Recreation and community activities	Information and knowledge
5	Detention basins	↘	↘	0	0	0	↘	↘	↘	↘	0	↘↗	↘	↗	↘	↘	↘	↘	↘↗	↘	↘↗	↘↗
5	Controlled retention areas	↘	↘	↘	↘	↘	↘	0	↘	↘	0	↗	0	0	↘	↘	↘	↘	↘	↘	↘	0
6	Dike relocation	↘↗	↗	↗	↗	↗	↘↗	↘	↗	↗	0	↗	↗	↗	↗	↗	↗	↘↗	↗	↗	↘↗	↗
6	Ecologically improved groynes	0	↗	0	0	0	0	0	0	0	0	0	0	0	0	0	↗	0	0	0	↘	0
6	Lowering floodplain/foreland	↘↗	↗	↗	↗	↗	↘↗	↘↗	↘↗	↗	0	↗	↗	↗	↗	↘↗	↘↗	↘↗	↘↗	↘↗	↘↗	↘↗
6	Sediment addition into riverbed	0	↗	↗	↗	↗	↗	↗	↗	↗	0	↗	↗	↗	↗	↗	↗	0	↗	↗	↘↗	↗
6	Removing obstacles	0	↗	0	0	0	↗	0	↗	0	0	↗	↗	0	↗	↗	↗	0	↗	↗	↘	0
7	Removal of bank fixations	↘	↗	↗	↗	↗	↘↗	↘	↗	↗	0	↗	↗	0	↗	↘↗	↗	↘↗	↗	↗	↘↗	↗
7	Removal of dams and weirs	0	↗	0	0	0	0	0	↗	0	0	0	↗	0	↗	0	↗	↘↗	↘↗	↗	↘↗	0
7	Lateral floodplain reconnection	0	↗	↗	↗	↗	↘↗	↘	↗	↗	0	↗	↗	↗	↗	↘↗	↗	↗	↗	↗	↘	↗
7	Channel, oxbow and pond creation	↘	↗	↗	↗	↗	↘↗	↘	↗	↗	0	↗	↗	↗	↗	↗	↗	↘	↗	↗	↗	↗
7	Construction of fish passages	0	↗	0	0	0	↗	0	0	0	0	0	0	0	0	0	↗	↘	0	0	↗	0
8	Creating natural habitat from forest	↗	↗	↗	↗	↗	↘↗	↘	↗	↘↗	0	↗	↗	0	↗	↗	↗	↗	↗	↗	↘↗	↗
8	Creating natural habitat from agro land	↘	↗	↗	↗	↗	↘↗	↘	↗	↗	↗	↗	↗	↗	↗	↗	↗	↗	↗	↗	↘↗	↗
8	Creating nat. habitat from extraction sites	↗	↗	↗	↗	↗	↗	↗	↗	↗	↗	↗	↗	↗	↗	↗	↗	↗	↗	↗	↘↗	↗
8	Control of invasive alien species	↗	↗	↘	0	0	↘↗	↘↗	↗	↘↗	0	↗	↗	0	0	↗	↗	↗	↗	↗	↗	↗
8	Creation of gravel banks	0	↗	0	0	0	0	0	↗	0	0	0	↗	0	0	↗	↗	↗	0	↗	↗	↗
8	Elimination of top soil	↘	0	↘	0	0	↘	↘	↘	↘	0	↗	↗	↘	↗	↘↗	↗	↘↗	↘	0	0	↘↗
8	Land use extensification	↘	↘↗	↗	0	0	↘↗	↘	↗	↗	0	0	↘	↗	↗	↗	↗	↗	↗	0	↗	↗
9	Recreational infrastructure	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	↘	↘	↘↗	↘	↗	↗
9	Recreational use of the floodplain	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	↘	0	0	0	↗	0

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» E-BIND Focus Group meeting 'Evidence-based improvements in the Birds and Habitats Directives (BHD) implementation: systematic review' (Brussels, June 2019).

Complete list of organizations consulted along the project

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